AUGUST 1959

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ILLUMINATING ENGINEERING

Journal of the
ILLUMINATING ENGINEERING SOCIETY

Information You Can Use

WAKEFIELD CEILING

DIFFUSERS

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2' x 3' Square Wave Acrylic Patterned

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2' x 3' Line Pattern Vinyl

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45-98A
2' x 2' Steel Louver 35° x 35°
½" Square Cell—White Enamel

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35-25A (Pink,
Yellow, Green, Blue)

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Diffuser, 2' x 2'

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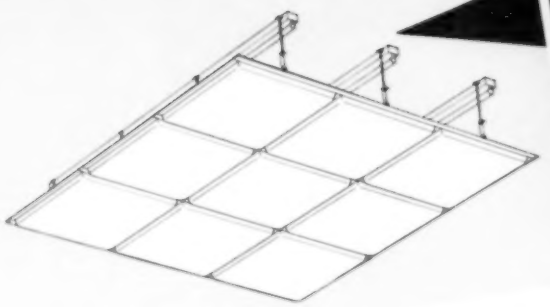
Diffuser Cover
for 35-35A
Diffuser, 3' x 3'

ORDER AS PER PLAN



Wakefield Ceiling gives the architect or engineer access to an infinite variety of wall-to-wall ceiling designs through the simple process of combining standard components. Diffusers and louvers vary as to style, pattern, texture, material and size. Color can be introduced through the use of inexpensive color filters. Baffles can be used both as sound absorbers and as color accents.

All grid tees are indexed on 12" centers. Electrical channels run crossvise to the runner tees. Tees and wall angles are extruded aluminum, finished aluminum.

Color filters for the 2' x 2' patterned diffusers available in pink, yellow, green, and blue.

Acoustical baffles formed of perforated steel and filled with Fiberglas, can be snapped on and off the grid tees at will.

Where the diffuser or louver cannot be cut to fit out room size, a luminous metal filler is supplied, sheared to size in the field. Available in white and in pastel shades of pink, yellow and green.

GRID

The grid consists of main runner tees exactly 8'0" long. These are suspended by threaded 3/16" steel rods from hook-on straps mounted on top of the electrical channels. Wall angles are cut exactly 8'0" long. Crosser tees are supplied in 2', 3' and 4' lengths, cut ready to use between main runner tees. All grid joints are made by a steel crimp connection which fits in a secure and trim manner. Light seals are provided to prevent light leaks at joints.

ELECTRICAL CHANNELS

Two standardized channels, 4' and 8' long, accommodate the Rapid Start lamps, 40 watt T-12. All channels are wired UL/CSA listed and ready for use. C.B.M. ballasts (HPF) are standard. Each channel includes two mounting straps for pre-fastening to the supporting structure. Suspension rods are available for deeper than 24" plenums.

ACOUSTICAL BAFFLES

Basic baffles are in standard lengths of 2', 3' and 4'. End caps eliminate baffle connectors. However, for continuing runs of baffles a joint connector is supplied. Rich metallic satin, matching the grid, is standard finish.

DIFFUSER COVERS

Luminous vinyl covers available for 3' x 3' line pattern vinyl diffusers and for 3' x 2' arc pattern vinyl diffusers.

SPECIFYING POINTS FOR ARCHITECTS AND ENGINEERS: Designed so lamps can be on any desired center and still support grid from strip. Hanger rods threaded and notched to field adjustment can be made. Extruded aluminum grid designed so acoustical baffles can be added or removed, without disturbing ceiling. Designed so color can be introduced by use of the 2' x 2' diffuser, acoustical baffles, and luminous filler.

This is one of several dozen "spec" sheets, printed on both sides, giving concise data on Wakefield's many commercial and industrial lighting units. We'll be glad to send them to you.

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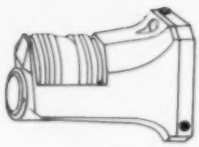
Revere Outdoor Lighting Report

Revere ELECTRIC MFG. CO.

Lighting a church exterior

The Problem: To provide distinctive, dramatic lighting for a church exterior. Fixtures must have wide, even light patterns and must be attached to the building itself.

The Solution: Revere No. 3151-A Underneath Floodlights were selected for their wide, flat light pattern. Because they are attached directly to the building, eliminating overhead arms, these underneath light fixtures are unobtrusive and blend in with architectural lines of the building. They are completely weather-tight.

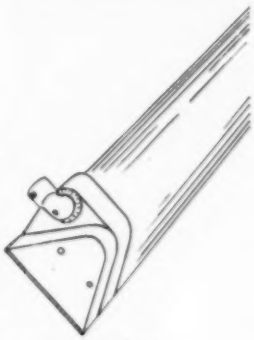


No. 3151-A
Underneath Floodlight

Lighting an automobile dealership

The Problem: To highlight the front of an automobile showroom exterior, showing to best advantage the face of the building and its distinctive identification.

The Solution: A continuous line of Revere Fluoresign luminaires were installed at cornice height, running the entire length of the surface to be lighted. The integral luminaires have an adjustable feature which permits accurate placement of light for smooth, even lighting. Enough spill light occurs on sidewalk for inviting atmosphere.



No. 8600
Fluoresign Luminaire

Lighting a service station

The Problem: To put an extremely high level of light on a service station's pump islands and service areas. Station must be unusually attractive to meet competition.

The Solution: Two Revere No. 7420 luminaires with 1000-watt color-improved lamps are mounted at a 14-foot height on each island. These provide a maintained average of 60 footcandles in the service area. Eliptor floodlights illuminate perimeter. High level of illumination has greatly improved station's competitive position.

No. 7420
Mercury Floodlight

Write for Revere's complete catalog of outdoor lighting equipment.

Revere ELECTRIC MFG. CO.

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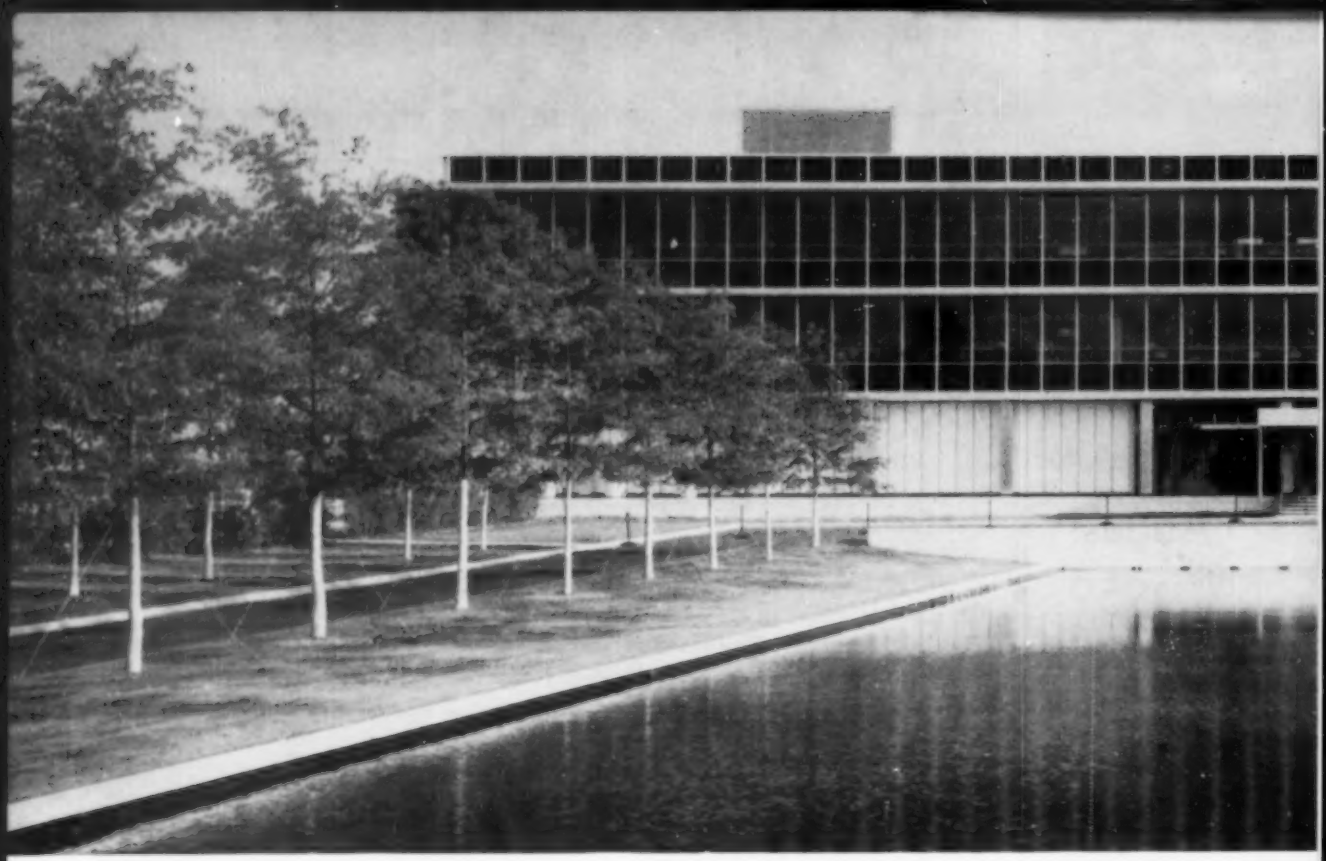

Maximum flexibility in space utilization is achieved at Reynolds through partitions that easily can be moved to expand or decrease area sizes. This can be accomplished without making costly changes in the lighting system. The Curtis wall-to-wall ceiling of light provides 80 ft. candles of maintained illumination. Attractive Hexcel Honeylite aluminum diffusers complement the inviting decor.

How a special Curtis Lighting system saved Reynolds Metals $50,000...

Here is the new home of Reynolds Metals Company, Richmond, Va. It is dramatically placed at the end of a reflecting pool bordered by willow oaks. The classic beauty of the building is enhanced by this unusual setting. Architect: Skidmore, Owings & Merrill; Consulting Engineer: Ebasco Services, Inc.

Unique all-aluminum folding grids in 100 sq. ft. units cut installation time 8,000 man hours . . . provided wall-to-wall illumination with low brightness quality

Installing a lighting system so flexible it can adapt to any internal building change without relocation is quite a feat. But when that is accomplished at important savings it calls for exceptional engineering ingenuity. That's what Curtis Visioneers achieved with a special custom-made aluminum folding grid system at Reynolds Metals Company, Richmond, Va. The unique folding "packages" made it possible to install 100 sq. ft. of lighting at one time. Result: a saving to Reynolds of an estimated 8,000 man hours, or approximately $50,000. A wall-to-wall ceiling of light was created with a beautiful satiny aluminum lighting tone of low brightness quality. Over-all ceiling illumination solved the problem of how to obtain stationary lighting for a 100,000 sq. ft. area, even though wall partitions would be moved in the future. Write today for the name and address of the representative in the principal city nearest you. Curtis-AllBrite Lighting, Inc. Chicago, 6135 W. 65th St./South San Francisco, 352 Shaw Road.

CURTIS All-Brite

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Young Ladies Appear in a Good Light Here

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You never had lighting like this when you went to school. Nor did the premises shown above until recently when Litecontrol 6628-HO fixtures replaced an incandescent installation and raised the footcandle level greatly.

The fixtures are hung from steel beams across this modern gym. The "HO" (High Output) Lamps produce almost half again as much light as the previous lamps of the same length — 7500 lumens against 5100 lumens. (Call it a 47 percent light increase — and that's good.) Equally, if not more important, is the even dispersion of the light throughout.

Lighting *costs* appear in a good light, too, when *standard* Litecontrol equipment is specified — on any commercial or industrial job.

INSTALLATION:
Bouvé-Boston School (affiliated with Tufts University), Medford, Massachusetts
AREA SHOWN:
Gymnasium
ELECTRICAL CONTRACTOR:
Warren H. Bennett, Inc., Medford, Massachusetts
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Westinghouse Electric Supply Company, Boston, Massachusetts
FIXTURES:
Litecontrol #6628-HO Pendant baffle fixtures, using F96T12/CW/HO High Output Cool White lamps.
SPACING: 7'-0" on centers
CEILING HEIGHT: 28'-0"
MOUNTING HEIGHT: 24'-0"
INTENSITY: Average, 55 footcandles in service

LITECONTROL

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The Effect of Specular Reflection on Visibility

Most visual tasks are seen by reflected light; very few are self-luminous. The reflected light may cause a task to be barely visible or easily visible. Some objects are more difficult to see than others. Why? What determines the visibility of an object? We do not have all the answers, but we do know that the spatial distribution of the reflected light certainly has a great deal to do with the answer to the question. The reflected light flux that causes the object to be visible originates in light sources that are disposed in space around the object while the observer views the object from a particular location. Thus, the geometry of the system which relates all of the directions, distances and dimensions is an important factor. Other parameters are the physical characteristics of the object, the directional intensity of the initial sources, and the psychophysical sensitivity of the observer. These papers will attempt to show some of the relationships among the first two groups of variables which relate to directional reflections.

There have been numerous prior researches in the general field of specular reflections and glare (see references 1-6, Finch paper). These have been helpful in pointing up the problem and have added much useful information to the field. It has been observed many times previously that specular reflections can greatly alter the contrast of a visual task. But, there had yet to be developed a method of quantitatively evaluating the change in contrast caused by various lighting systems. Such quantitative procedures are reported herein and verified by physical measurements of contrast and subjective measurements of contrast through subjective measurements of visibility.

In 1955 Chorlton and Davidson carried out experiments in a grade school classroom to determine if specular reflections at the task were significant. The tests showed an appreciable loss in contrast due to specular reflections. As a result, Finch of the University of California, Berkeley, Calif., was commissioned by the Illuminating Engineering Research Institute, New York, to make a similar study using 30 footcandles and also higher footcandle levels. Chorlton and Davidson repeated their work up to 70 footcandles. The initial studies in Toronto indicated that visibility changes did occur under various lighting systems. Specular reflections were shown to be deleterious but the variations in visibility had to be identified with physical changes before the results could be fully accepted. The obvious thing to do was to determine the changes in brightness that occurred when the lighting was changed, so that the actual contrast could be obtained. These measurements are easy to describe, but difficult to make. Some data are now available and are described in the paper by Finch beginning on the following page. The subjective contrast or visibility measurements are described in the second paper by Chorlton and Davidson, beginning on page 482. The work on the physical measurements was done at the University of California, Berkeley. The field visibility measurements were made principally in the schools in Toronto, Ont., with some check tests made in California.

Isaac Goodbar, consulting engineer and mathematician, New York, N. Y., as an IERI research project, developed a graphical method for computing the task contrast in a given lighting situation from physical measurements. This is presented beginning on page 489.

The Effect of Specular Reflection on Visibility

Part I—Physical Measurements for the Determination of Brightness and Contrast

By D. M. FINCH

CHANGES in visibility occur when visual tasks are viewed under various lighting conditions even though the illumination at the task may be constant. These changes in visibility are related to the change in the brightness patterns of the detail and background and the contrasts that result. We shall attempt to define more precisely the parameters that are involved in the contrast changes.

Sample Visual Tasks

The materials tested include typical schoolroom samples of printed ink material on matte type paper (Sample A-2), printed ink on coated book stock (Sample A-1) and boy's handwriting samples using pencil on a ruled foolscap paper (Sample 8-11). Refer to Figs. 22, 23 and 24.

The visual tasks were first observed and visually evaluated under several typical lighting systems. See Fig. 1. Brightness data were then taken on each task to permit the actual contrast to be calculated for each lighting system. The physical brightness measurements on the task involved the use of a microphotometer to determine the brightness of a small area approximately 0.015 inch in diameter for various viewing and incidence angles at known levels of illumination. After such measurements were made, Brightness Factors (see later section) were computed which permit the actual brightness of a task to be determined for any lighting system.

The Lighting System

A typical schoolroom lighting system was set up in a laboratory room at the University of California, Richmond Field Station. The room selected was approximately 25 by 30 feet with a ceiling 9 to 14 feet high. Open wooden trusses supported a hipped roof. The lighting units were attached to the bottom chord of the roof trusses 9 feet above the floor. See Fig. 2. The ceiling and roof trusses were painted white at approximately 65 per cent reflectance. The walls above bench height were pale green at 60 per cent reflectance and the floor was brown linoleum, 20 per cent reflectance.

The lighting consisted of fluorescent lighting

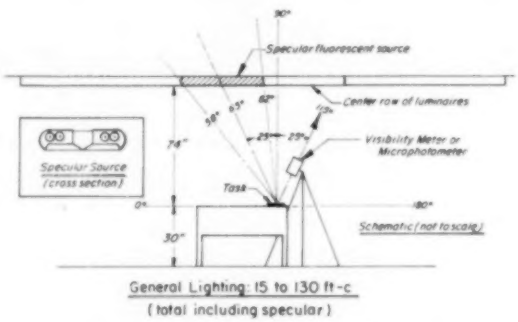

Figure 1. Schematic diagram of test set-up. The specular source consisted of four 40-watt T12 rapid-start white fluorescent lamps up to and including 3000 fL; two lamps per side. About 6, 18 or 48 inches of tube length were visible, the remainder of tube length masked. At 3000 fL, specular source produced 5 to 22 footcandles at the task (depending upon length of exposed source). Luminaires were equipped with top reflector plates for 40- to 130-footcandle levels and were without top reflector plates for the 15- to 30-footcandle levels. Above 3000 fL, an incandescent floodlamp was substituted for the fluorescent source. The incandescent specular source was masked to 1¼-inch diameter opening and contributed up to 11 footcandles on the task. The incandescent source was placed in line with the fluorescent specular source and at the same orientation. The fluorescent specular source was turned off for the measurements above 3000 fL.

AUTHOR: Research Engineer, University of California, Berkeley, Calif. This report is sponsored by the Illuminating Engineering Research Institute as Project #52 (and supplements thereof). Approved by the Research Executive Committee and the Board of Trustees.

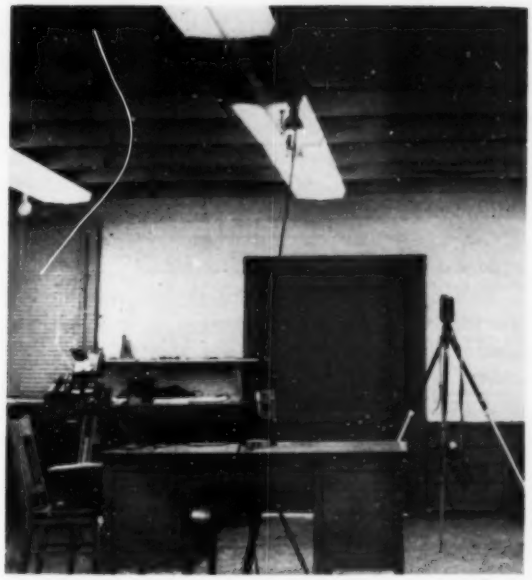

Figure 2. Experimental room set-up. General arrangement at University of California, Berkeley. Spectra microphotometer measuring task brightness.

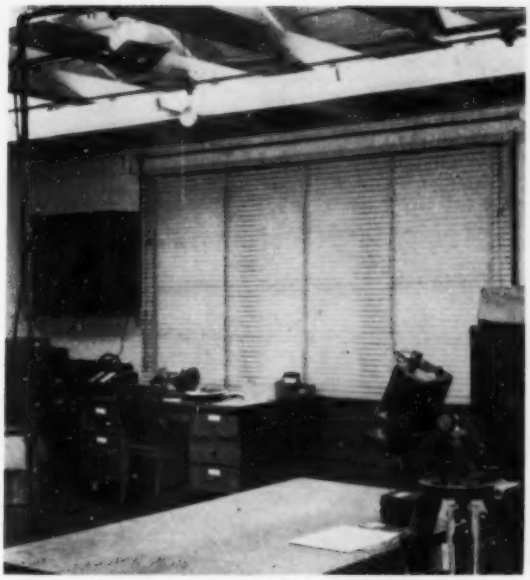

Figure 3. Experimental room. Measuring instruments at location of observer's head showing minimum shielding.

units arranged in three longitudinal lines on 7-foot 3-inch centers. Each unit had four 96T12, 8-foot fluorescent lamps and was provided with plastic side panels and louver bottom baffles to give approximately 30-degree shielding.

The Test Location

The samples were located on a desk in the center of the room directly under the center row of lighting units. The observer's line of sight was at 25 degrees to the normal (115 degrees to the reference direction in the plane of the task). The brightness measuring instruments were placed at the location of the observer's head in such a manner that a minimum of shielding occurred insofar as the light on the sample was concerned. See Fig. 3. None of the light in the specular zone nor from the front and side was shielded. The setup was typical of all lighting systems in which an actual observer looks at sample material.

Physical Brightness Measurements On the Test Samples

In order to evaluate the changes in contrast that occur under different lighting conditions, an arrangement was set up so that the actual brightness of the printed material and penciled lines and their backgrounds could be obtained by physical means. Two instruments were used as microphotometers as shown in the photographs in Figs. 4 and 5. The goniometer mounting stand for the test sample, designed to be as nearly universal as practical for the viewing and incident angles, is shown in Fig. 5.

Spectra Microphotometer

One of the microphotometers was a modified Spectra Model TT1 Brightness Meter,[13] made by the Photo Research Corporation, which was capable of measuring small areas down to 0.015-inch in diameter, at 1.6 inches ahead of the objective lens which was closed to an aperture ¼-inch in diameter. The outside dimensions of the instrument somewhat limited the angles of incidence and viewing that were possible but this was not serious because all of the angles that are normally used in reading and writing were available. The initial Spectra Meter

Figure 4. Spectra microphotometer set-up used to measure task brightness factors in experimental room.

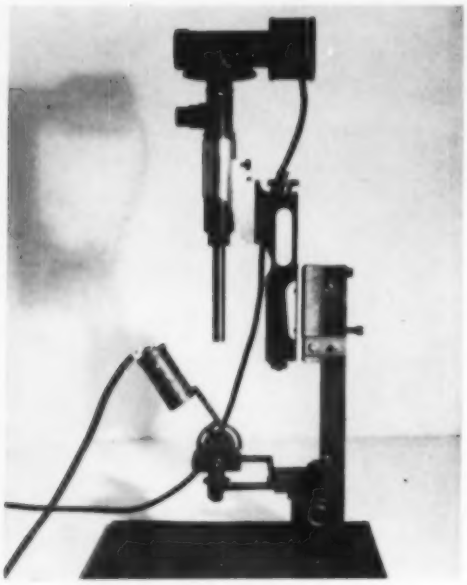

Figure 5. U. C. microphotometer on goniometer stand.

employed a split-field optical system in which a partial mirror operated in conjunction with the photocell. After preliminary measurements it was noted that polarization affected the brightness readings and that there was the possibility that the measurements at certain angles of incidence and viewing were reduced (or enhanced) by the polarized component in the light. The instrument and the optics have been redesigned so that the polarization effect is now eliminated.

U. C. Microphotometer

While the Photo Research Corporation was working on the re-design of the Spectra microphotometer to eliminate the polarization effect, a non-polarizing microphotometer was constructed at the University of California which would permit measurements to be made within a wider range incidence and viewing angles. The developed device is shown in the photograph of Fig. 5. This instrument has a small acceptance angle of approximately 2 degrees which corresponds closely to the total acceptance angle of the eye at reading distances. Also the incident light source can be brought close to the line of observation so that a wide range of angles can be covered.

The sensitivity of both meters is adequate to measure the blackest ink that has been found and will measure the whitest paper that is used.

Brightness Measurements

The initial brightness measurements were made on the samples used for the visibility studies under the identical lighting conditions that were employed for the visibility meter evaluations. In this way, the photometric brightness of the ink and pencil and the paper background was determined for the composite lighting arrangements that were used. With the measurements thus obtained the actual contrast for each lighting condition was calculated and the change in contrast from one lighting condition to another was determined. The data are reported in the section on "Results."

In addition to the above brightness readings the samples were measured to obtain their Brightness Factors[11,12] using a point light source. The light source was located at various angles of incidence while the observation angle was held constant at 25 degrees to the normal (115 degrees to the 0-degree reference in the plane of the task).

Brightness Factors and Their Use

The general concept of the directional reflectance of materials needs further discussion. This discussion will be limited to ordinary surfaces that are intermediate between perfectly diffuse and smooth plane mirrors. The smooth mirror is a special case that is not usually encountered but can be handled by the laws of specular reflection. Consider a semi-diffuse surface that is illuminated by a specific source and is observed to have a known brightness in a particular direction. The brightness must be measured using a small solid angle similar to that of the observer. If the ratio of the brightness to the illumination is taken a factor can be determined that is a characteristic of the material for these particular conditions. This quantity is defined as the ***Brightness Factor*** for the specific angle of observation and location and size of incident light source. Then the ***Illumination*** normal to the surface may be ***multiplied*** by the ***Brightness Factor*** to obtain the ***Brightness*** in the particular direction. Every non-mirror surface will have its own particular

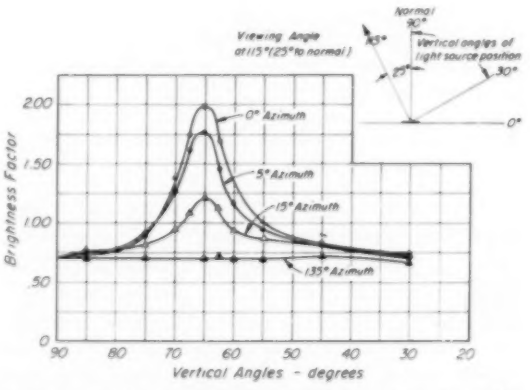

Figure 6. Background: Sample A-1 (coated book stock).

characteristic pattern of brightness factor, depending upon the material, texture, spectral absorptance and reflectance, and other intangible qualities usually referred to as sheen or gloss.

The Brightness Factor is defined by the equation:

$$\text{Brightness} = \text{Illumination} \times \text{Brightness Factor}$$

If the illumination is in footcandles normal to the surface, the brightness will be in footlamberts if the curves of this paper are used. The curves of Figs. 6-21 have been obtained by taking the ratio:

$$\frac{\text{Brightness (fL)}}{\text{Illumination (fc)}} = \text{Brightness Factor}$$

As the angle of incidence changes, the brightness of the background and/or the object on the back-

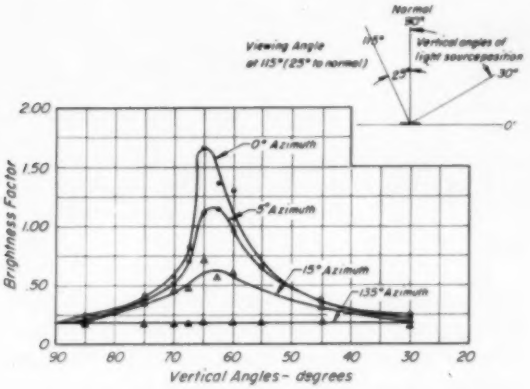

Figure 7. Ink: Sample A-1 (coated book stock).

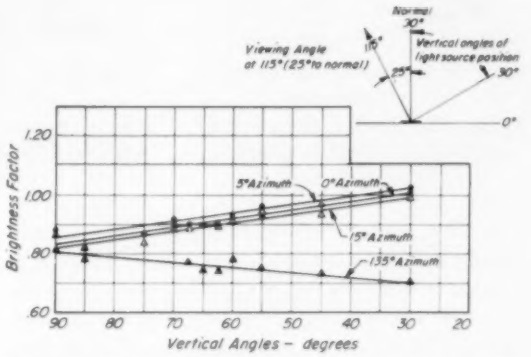

Figure 8. Background: Sample A-2 (matte book stock).

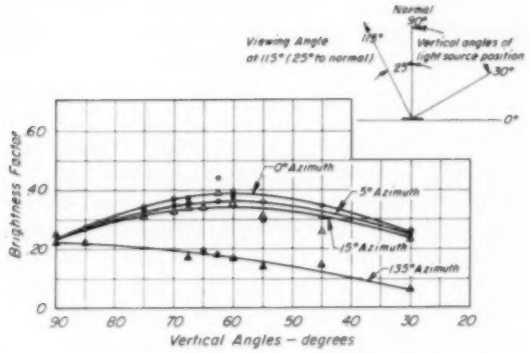

Figure 9. Ink: Sample A-2 (matte book stock).

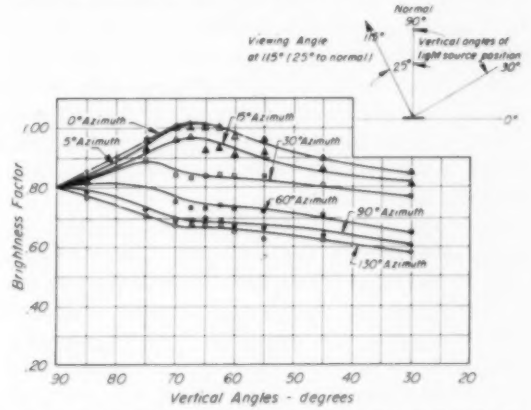

Figure 10. Background: Sample 8-11 (boy's handwriting).

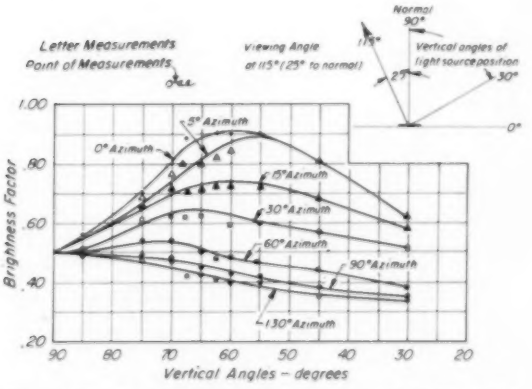

Figure 11. Pencil (Letter No. 1): Sample 8-11 (boy's handwriting).

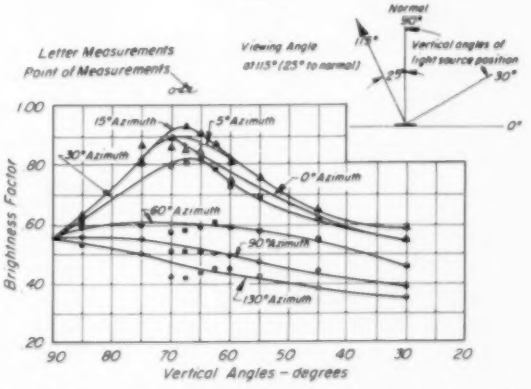

Figure 12. Pencil (Letter No. 2): Sample 8-11 (boy's handwriting).

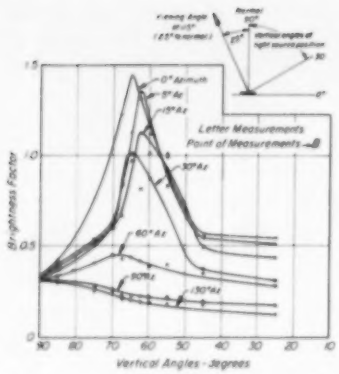

Figure 13. Letter: Sample 8-11 (boy's handwriting in pencil).

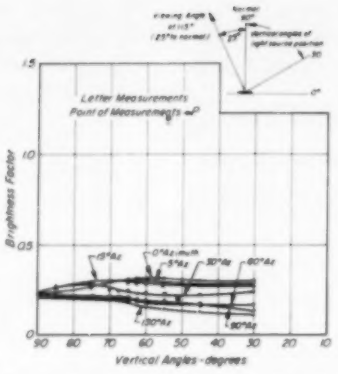

Figure 14. Letter: Sample 2 (typed original, IBM typewriter on white bond).

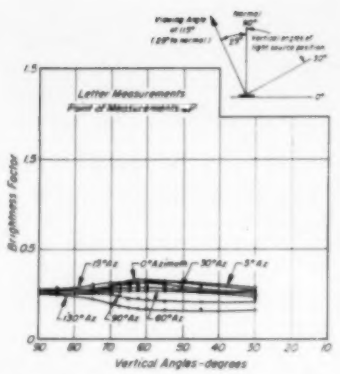

Figure 15. Letter: Sample 3 (typed fourth copy, IBM typewriter on white bond, good carbon).

ground may change extensively. The photographs in Figs. 22-24 show what happens to the contrast of ink printing and to pencil line work when the angles of incidence are changed. These changes are so important that they need to be studied in great detail. It is quite possible for the contrast to change from negative to positive on some materials because of reflected light from the specular zone. Also, over a wide range of angles, the brightness of the object may be approximately equal to its background, which reduces the contrast to close to threshold. Refer to Figs. 10-13 for Sample 8-11 which indicates the above effect.

The ratio of *total reflected* to *total incident* flux is the conventional "reflectance" of the material. This "reflectance" is another characteristic of the material and has significance in many problems *but the "reflectance" cannot be used to obtain the brightness in a particular direction* except under the special conditions of perfect diffusion or plane surfaced mirrors. The details in a seeing task are usually either semi-diffused or semi-specular and they are always viewed from a particular direction and they are generally lighted from a series of specific directions or from an area source having a range of direction angles. Therefore, if the brightness of the task is to be determined as it appears to an observer, it is necessary to have data on the directional reflectance characteristics of the task for various angles of incidence of the light.

Test Results and Discussion

These tests disclose the fact that the specific arrangement of luminaires used to produce the illumination was important because change in contrast also occurred. *It was noted that when the physical contrasts of a task under two different lighting systems were equal, the Visibility Indices were also equal.* This important conclusion was the basis for later work on physical contrast measurement.

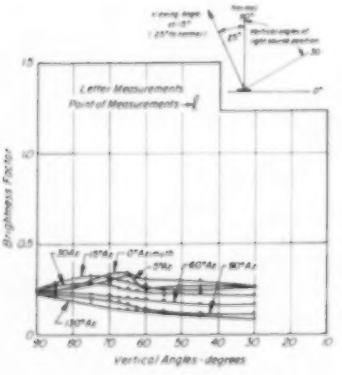

Figure 16. Letter: Sample 4 (fountain pen on white bond).

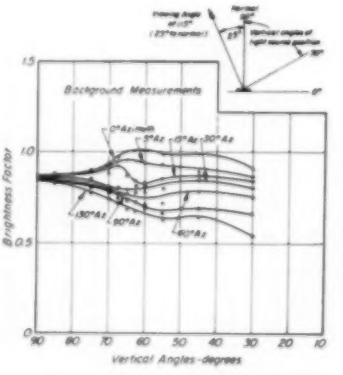

Figure 17. Background: Sample 4 (fountain pen on white bond).

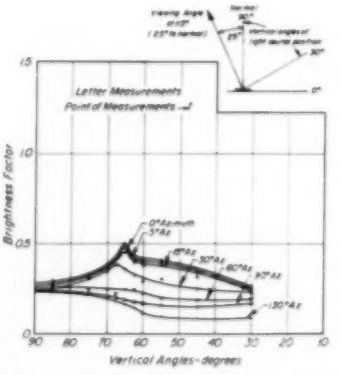

Figure 18. Letter: Sample 1 (typical Verifax).

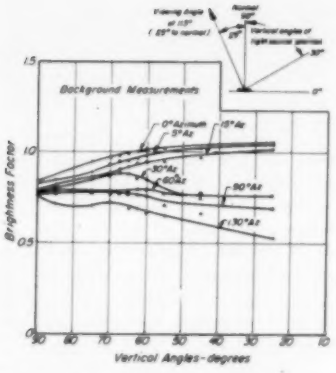

Figure 19. Background: Sample 1 (typical Verifax).

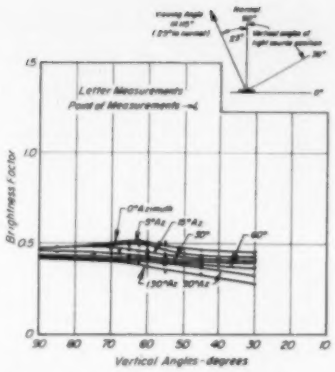

Figure 20. Letter: Sample 5 (Ozalid print, gray background).

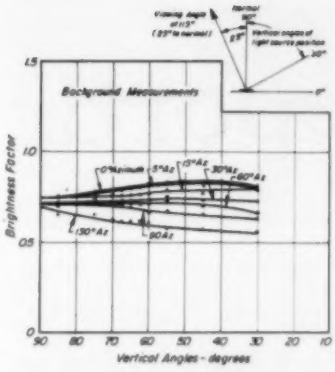

Figure 21. Background: Sample 5 (Ozalid print, gray background).

Results of Brightness Measurements

Following the development of the above basic conclusion it was decided to attempt to verify the idea by making specific brightness and contrast measurements on all of the sample tasks under all of the light conditions that prevailed. Therefore, the brightness of each task and its background was measured using the microphotometer with: (1) the general lighting only, (2) the specular lighting with either 48-, 18- or 6-inch long fluorescent sources, or a 1½-inch diameter incandescent source, (3) a source over the right shoulder of the observer, and (4) combinations of these. The Brightness Factors and the corresponding contrasts are given in Table I.

The data in Table I show that the contrast for Sample A-1 varied from 88 per cent to 31 per cent for the lighting conditions used while the contrast for Sample 8-11 changed from 43 per cent to 9 per cent. These are quite remarkable changes and begin to account for variations in the observed visibility under different lighting conditions.

It is now certain that the light distribution is important in developing contrast and can hardly be overemphasized. Under actual lighting conditions the effects of light distribution are dramatically shown in the photographs of Figs. 22 to 24. However, it is very desirable to have a calculation procedure that will permit the contrast to be predetermined in the design stage before the construction and installation of the lighting system.

The calculations for contrast for any lighting system can be made if the Brightness Factors for each task have been evaluated. Figures 6 to 21 show the results of such measurements on Samples A-1, A-2 and 8-11. To use these data one must consider how each individual lighting element contributes to the total brightness of the task. The components of

TABLE I — Measured Brightness Factors and Contrast Using Spectra Microphotometer.

	Sample A-1 (Coated Book Stock)				Sample 8-11 (Boy's Pencil Handwriting		
	Brightness Factor				Brightness Factor		
Condition	Ink	Paper	Contrast (Measured)	Contrast (Calculated)	Pencil	Paper	Contrast (Measured)
Back light only—incandescent light—over right shoulder, back 30 inches, to the right 30 inches from task (6 fc)	.082	.67	88%	81%	.37	.65	43%
General lighting —plus back lighting (30 fc total)			82%				33%
General lighting only—three rows of 2-lamp fluorescent, all on except one 4-foot unit at the glare angle (30 fc)	.20	1.02	78%	74%	.65	.92	29%
General lighting plus two 48-inch fluorescents with centers at glare angle (30 fc)			66%	63%			24%
Two 48-inch fluorescents with centers at glare angle, left lamp lined up for maximum brightness factor (11 fc)	.61	1.06	42%		.80	.94	15%
One 48-inch fluorescent with center at glare angle (5.5 fc)	.72	1.27	43%	33%	.86	.97	11%
One 18-inch fluorescent with center at glare angle	.88	1.35	35%		.92	1.01	9%
1¼-inch diameter incandescent at glare angle (25 degrees) (6 fc)	1.20	1.74	31%	26%	.95	1.05	9%

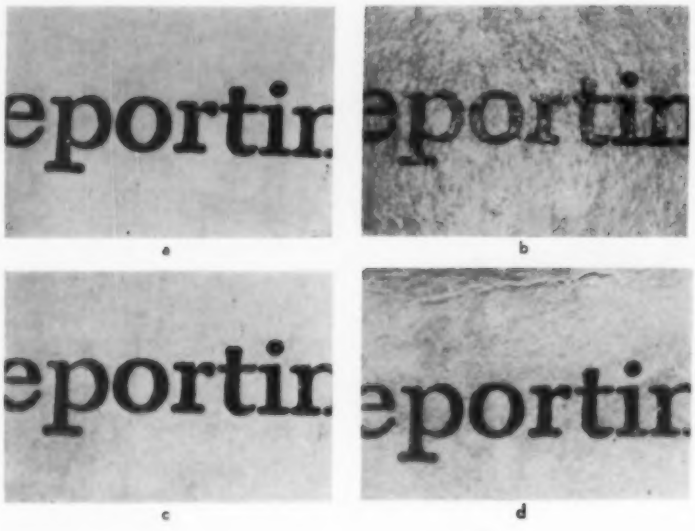

Figure 22. Sample A-1, coated book stock, (a) 90 degrees incident light, 115-degree viewing angle. (0 degrees reference in plane of paper.) (b) 65 degrees incident light (specular angle), 115-degree viewing angle. (c) 40 degrees incident light, 115-degree viewing angle. (d) 5 degrees incident light, 115-degree viewing angle.

brightness are directly additive. Each individual effect is then added to the others to get the total brightness as seen by the observer.

For example, *we can now compute the contrast of Sample A-1,* (printed ink on coated book stock) for several lighting systems each providing 30 foot-candles illumination.

The first lighting arrangement could consist of the three rows of fluorescent luminaires providing direct lighting plus indirect light from the ceiling. One 48-inch luminaire at the angle of specular reflection could be omitted. This would be the case of general lighting only without specular reflection from the critical zone. Fortunately, the calculations are simplified for Sample A-1 because the omission of the one 48-inch luminaire at the specular angle will eliminate all of the Brightness Factors between 58 degrees to 82 degrees on the curves of Figs. 6 and 7 and will make it possible to use average Brightness Factor for the remaining direction as follows:

$$\text{B.F. background} = 0.95 \text{ (average)}$$
$$\text{B.F. ink} = 0.25 \text{ (average)}$$
$$\text{So: Contrast} = \frac{0.95-0.25}{0.95} = .74 \text{ or } 74 \text{ per cent (1)}$$
$$\text{General Lighting Only}$$

(Compared to 78 per cent measured)

Similar calculations were made to determine values indicated in Table I.

For the condition of general lighting plus two

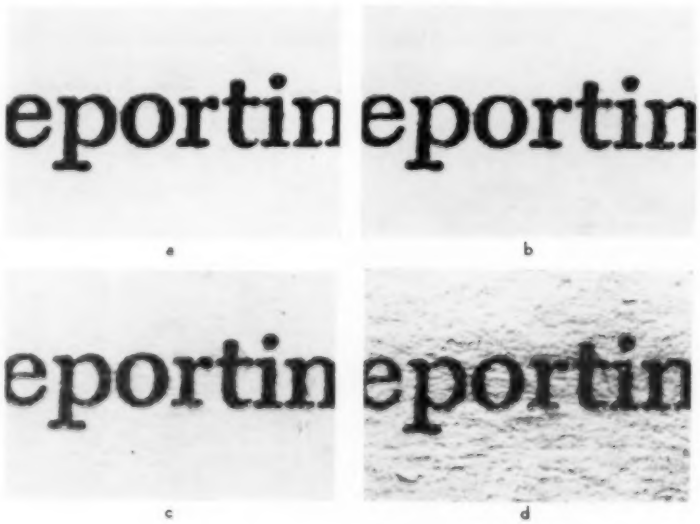

Figure 23. Sample A-2, matte book stock. (a) 90 degrees incident light, 115-degree viewing angle. (0 degrees reference in plane of paper.) (b) 65 degrees incident light (specular angle), 115-degree viewing angle. (c) 40 degrees incident light, 115-degree viewing angle. (d) 5 degrees incident light, 115-degree viewing angle.

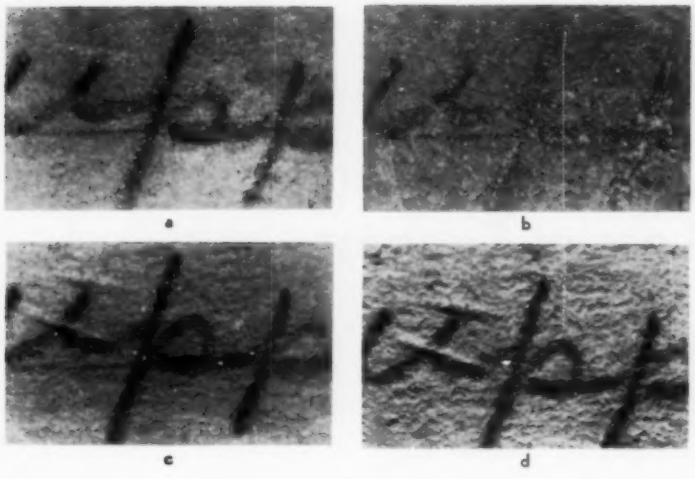

Figure 24. Sample 8-11, boy's pencil handwriting. (a) 90 degrees incident light, 115-degree viewing angle. (b) 65 degrees incident light (specular angle), 115-degree viewing angle. (c) 40 degrees incident light, 115-degree viewing angle. (d) 5 degrees incident light, 115-degree viewing angle.

48-inch fluorescent lamps at the angle of specular reflection the calculation of contrast would be:

Source	Illumination	Contrast of Sample A-1 B.F. Paper	B.F. Ink	Brightness Paper	Brightness Ink
General Lighting	19 fc	0.95	0.25	19.0 fL	4.7 fL
2 48-inch Fluorescent Lamps (at specular angle)	11	1.06	0.61	11.7	6.7
	30 fc			30.7 fL	11.4 fL

$$\text{So: Contrast} = \frac{30.7 - 11.4}{30.7} = \frac{19.3}{30.7} = 63 \text{ per cent} \quad (5)$$

General lighting plus 2 48-inch fluorescent lamps at specular angle.

(Compared to 66 per cent measured)

The calculated values are in general agreement with the measured values although the calculated values are slightly low for all conditions. The averaging procedures are probably inaccurate to the degree indicated by the difference between measured and calculated values. These checks provide a basis for confidence in the calculation procedure.

Now, assume that the illumination is increased by adding more lighting units in a room. How would the contrast change for Sample A-1 (coated book stock)?

Assume that the brightness due to specular reflection remains constant from two 48-inch fluorescent lamps at the angle of specular reflection and that the additional fluorescent lamps are all at 2000 fL brightness. The viewing angle is assumed to be 25 degrees to the normal (115 degrees in Figs. 6 and 7). The calculations will give the following data:

Illumination (fc)		*Contrast (per cent)*
11	(2 48-inch fluorescent lamps	42
15	(2 48-inch fluorescent lamps plus additional lamps)	51
30		67
40		70
80		76
120		77

The technique for making contrast calculations is outlined. Some of the basic data necessary for calculating the change of contrast are given. It should be possible for a lighting specialist to consider such material and to arrive at a reasonable lighting design which will insure that a preselected loss in contrast will not be exceeded.

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The Effect of Specular Reflection on Visibility

Part II—Field Measurements Of Loss of Contrast

By J. M. CHORLTON
H. F. DAVIDSON

FIELD STUDIES have been conducted over a period of years commencing in 1955 by the authors in order to determine if specular reflections in written and printed visual tasks resulted in a measurable loss in contrast and consequent loss in visibility.

Earlier Studies

The earlier experimental work[1] was carried out on the assumption that the effect of specular reflections on the visibility of the task was primarily a function of the brightness of the light source at the mirror angle and of the glossiness of the task. As a result, the task was located at such a position that if a mirror replaced the task, the observer would see part of one of the lamps at the location of the letter that was to be used for the visibility measurement. The loss of contrast was determined for several lamp brightnesses but only the lamps in the luminaire at the glare position was changed. The change in lamp brightness was obtained by using ballasts that provided 200, 300 or 430 milliamperes lamp current. The experimental results were plotted as per cent loss of contrast against lamp brightness.

Further experimental work indicated that it was not the brightness of the glare source that was the criterion but rather the proportion of the total flux on the task that was incident in the direction of the mirror angle to the angle of view of the task. The earlier method, that is, changing the brightness of the lamps in the one luminaire only, showed slightly greater losses than would have been obtained if all the lamps in the room had been changed. Current results are therefore referred to the lighting system or geometry rather than the lamp brightness, because under any given condition all of the lamps in the room were at the same brightness.

Visual Tasks

The pencil tasks were selected as typical from a large number of samples of children's handwriting collected from grade schools. All of the pencil tasks were written with HB (#2) pencils on ruled matte white paper which had a diffuse reflectance of 77 per cent. The pencil tasks are designated in the tables and photographs as 8-3, 8-5, 8-11, 6-2, 6-9 and N.J.

Two printed tasks are designated in the tables and photographs as A-1 and A-2 and were identical except for the paper. They were printed with the same ink on the same machine with A-1 being printed on a "coated book stock" which was quite glossy and A-2 printed on a matte white paper, "offset book stock." The diffuse reflectance of the A-1 paper was 84 per cent; that of the A-2 paper was 88 per cent. A third printed task is designated as LM and was 8-point Bodoni book type on a good white matte paper.

In each of the tasks, a lower case letter "e" was selected as the object of regard to be used in the visibility measurements. The word in which the test letter was located was circled so that the same letter in each task was always used. (See Fig. 1 a, b, c, d.)

Visibility Meter

A Cottrell Contrast-Brightness Threshold Meter was used to measure visibility of the task under various conditions. The construction of this meter is described in the literature[2]; the only changes made in the meter were the addition of an artificial pupil 2 mm in diameter and the addition of one horizontal and two vertical cross-hairs to permit

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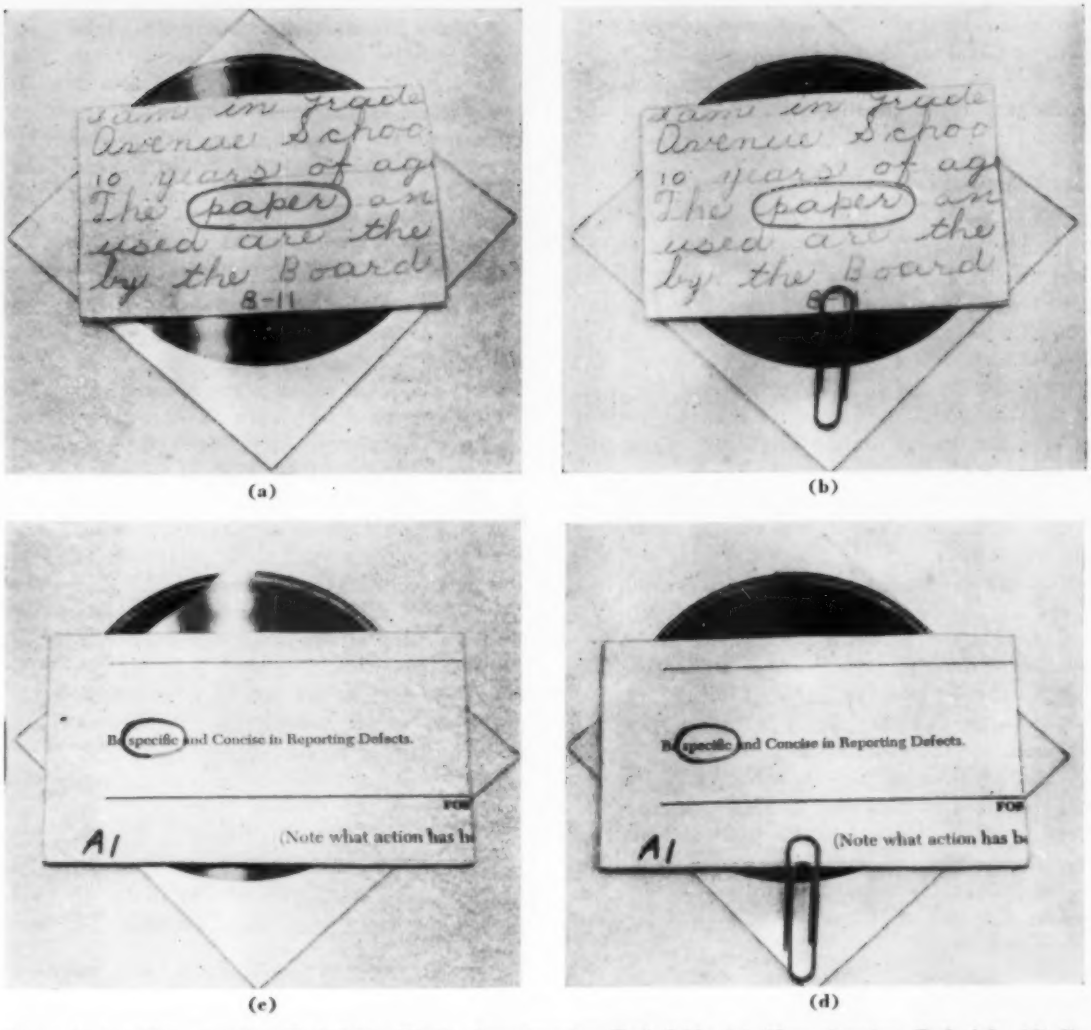

Figure 1. (a) Glare situation, Task 8-11; (b) No glare situation, Task 8-11; (c) Glare situation, Task A-1; (d) No glare situation, Task A-1.

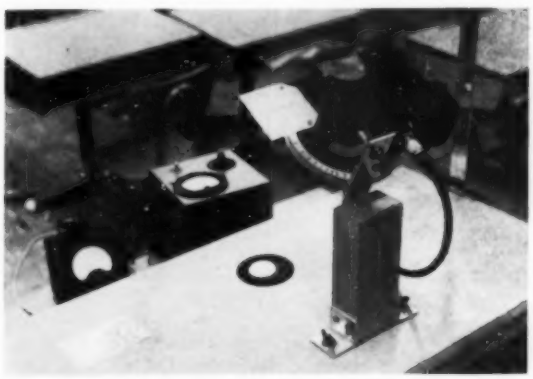

Figure 2. Close-up of visibility meter in position.

location of the test letter at the same place each time. The meter was fastened to a support in such a manner that the task was 14 inches from the artificial pupil and the line of sight of the observer was 25 degrees from normal to the task (Fig. 2). The angle of view of 25 degrees was selected on the basis of an unpublished report made to the IES School Lighting Committee by a Subcommittee on Visual Problems. This report indicated that an angle of view of 25 degrees was very common with children doing desk work. It is anticipated that measurements will be carried out at other angles of view at a later date.

The Cottrell Meter yields a threshold contrast-factor. By making observations on the task under different lighting conditions, different contrast-

factors are obtained. The difference in measured contrast-factor under the two conditions is taken as a measure of the difference in apparent contrast in the task due to the difference in lighting conditions.

Test Table and Instruments

A table was constructed to accommodate the task, footcandle meter and the visibility meter with its controls and the "no glare" shield. Figure 2 shows a close-up of the top of the test table. The visibility meter is shown fastened to its support which positions the meter and the angle of view. The control box for the visibility meter is at the front of the table and is used to adjust the lamp current to give the desired veiling brightness within the visibility meter.

A cosine-corrected photocell is recessed in the middle of the table top so that the top surface of the cell is flush with the top of the table which is 30 inches above the floor. The photocell is connected to the left hand meter at the front of the test table and indicates the illumination incident at the location of the task. With the operator in position the footcandle level is adjusted to the desired amount after which the task is placed on top of the photocell for the visibility measurements.

The brightness of the task background (paper) was measured by means of a photoelectric Spectra Brightness Spot Meter[3] having a field of view of ½ degree. For this measurement the brightness meter was at the same position as the visibility meter. The task brightness was measured for each condition of illumination and the veiling brightness of the visibility meter adjusted to this value. The Spectra Brightness Spot Meter was also used to measure ceiling brightness between the rows of luminaires. The lamp brightness was measured by means of a photocell and tube which measured the average brightness across the total width of the lamp.

Glare and No-Glare Conditions

For each lighting condition and location in the room, measurements of tasks were made under conditions of "glare" and "no-glare." The "glare" condition refers to the situation where no light is obstructed from the task other than by the observer and the visibility meter. This "glare" condition, illustrated in Fig. 3a is the normal condition that exists under the lighting system. The "no-glare" condition was obtained by intercepting light in a solid angle in the direction of mirrored reflection from the angle of view. The light was intercepted by a semi-circular shield, illustrated in Fig. 3b, which, when lowered to the horizontal position, excluded light in the solid angle subtended at the task by a vertical angle at 45 degrees and a vertical plane through the task at right angles to the direction of view.

Test Locations in Room

Figure 4 is a plan of the room showing the test locations A10, AB15 and B15. Location A10 was directly under the center row of luminaires and 10 feet from the rear wall. Location B15 was

(a)

(b)

Figure 3. (a) Glare condition. View of test table with shield in vertical position and observations being made. The control panel in the corner of the room is used by recorder to adjust illumination level when the conditions are changed from "no glare" to "glare." (b) No glare condition. View showing shield lowered to horizontal position to intercept light falling on the task in the direction of the glare.

TABLE I—General Diffuse Luminaires

	Per Cent of Luminaire Output		
	0-60 Degrees	60-90 Degrees	90-180 Degrees
4 Lamps	40.6	4.9	54.5
2 Lamps	46.4	5.3	48.3

TABLE II—Direct Lighting Luminaires

	Per Cent of Luminaire Output		
	0-30 Degrees	30-60 Degrees	60-90 Degrees
4 Lamps	38.8	51.0	10.2
2 Lamps	38.7	52.1	9.2

directly under an outside row of luminaires and 15 feet from the rear wall. Location AB15 was midway between rows and 15 feet from rear wall.

During all tests the window wall was covered by opaque drapes which were light buff in color.

Lighting Systems

Measurements were made in the test room under general-diffuse, direct and luminous indirect lighting systems. In each case the location of the luminaires was as shown in Fig. 4 and they were suspended 18 inches from the ceiling. The ceiling height of the room was 10 feet. It was hoped that illumination levels of at least 30 and 70 footcandles could be obtained at the three test locations. Unfortunately for the "no glare" condition, the screen cuts off a large amount of light and it was not always possible to maintain the 70 footcandles for the "no glare" condition. For this reason some of the data given is for 55 rather than 70 footcandles.

The general-diffuse system consisted of four-lamp, 48-inch luminaires mounted in three rows of six luminaires each. The luminaires had metal side-panels, louvered bottoms and open tops. Shielding was 35 degrees crosswise and 30 degrees lengthwise. Lamps were operated on dimming ballasts and were wired so that the outside two lamps in each luminaire could be turned off when an illumination level of 30 footcandles was desired. The luminaire distribution was as given in Table I. For 30-footcandle (2 lamps per luminaire) "glare" condition the average lamp brightness was 800 footlamberts. For the 70-footcandle "glare" condition the average lamp brightness was 1000 footlamberts (4 lamps).

The direct lighting system was obtained by placing metal covers over the general diffuse luminaires described above. The distribution of light from the "direct" luminaires was as shown in Table II. The average lamp brightness for the "glare" condition of 30 footcandles (2 lamps) was 1050 footlamberts and for the 55-footcandle level (4 lamps) the average lamp brightness was 1200 footlamberts.

The luminous indirect system consisted of three rows of two-lamp plastic-shielded luminaires which emitted 19.7 per cent of the luminaire output in the 0-90 degree zone. The lamps had a rated lamp current of 1.4 amperes and were connected into a

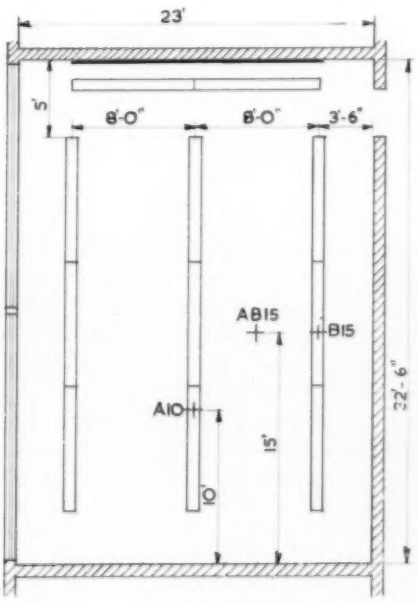

Figure 4. (left) Plan of test room showing the test locations A10, AB15 and B15 and the location of the three rows of luminaires. Ceiling height, 10 feet.

Figure 5. (below) View of test room showing the general-diffuse lighting system.

special dimming circuit which allowed operation of the lamps from full output to approximately 40 per cent of full output. The plastic shields had a brightness of approximately 300 footlamberts under the "no glare" condition. One lamp in each luminaire was turned off for the 30-footcandle level.

Ceiling Brightness

The ceiling brightness varied appreciably for both the general-diffuse and indirect lighting systems. In both cases the ceiling brightness midway between rows was about 15 per cent of the ceiling brightness directly above the center row of luminaires. Although this indicated that a lower mounting height for the luminaires would be desirable it was felt that the 18-inch suspension used was in accord with current practice. See Fig. 5 which illustrates the general-diffuse system.

The ceiling brightness for the direct lighting system was quite uniform but of a very low value in the region of 14 to 16 footlamberts.

Measurement Procedure

The steps in making the measurements of visibility were as follows:

(1) With the observer in place and the shield vertical (glare condition), the footcandle level was adjusted to the desired value and the task placed in the test location on the photocell.

(2) The veiling brightness in the visibility meter was adjusted to the brightness of the task background.

(3) The threshold setting was obtained by turning the graded filter from a point where the task could not be seen to the point where the letter "e" could be just seen and the filter transmission recorded. Five such observations were made successively and their average value obtained from which the threshold contrast-factor was calculated.

(4) The task was removed from the photocell and the semi-circular shield lowered to the horizontal position (no glare condition). The light output of all of the luminaires was increased uniformly to offset the loss of flux by the shield. The illumination was increased until the background brightness of the task was at the same value as under the "glare" condition. This was the same or a few footcandles higher than the "glare" condition depending on the degree of "glossiness" of the paper. In this method the veiling brightness spot in the visibility meter was kept constant for the "glare" and "no glare" conditions. In earlier work the illumination was maintained constant for "glare" and "no glare" and the veiling brightness spot adjusted. It was felt that by keeping the veiling brightness the same for both conditions there would be less chance of error both in setting the brightness and in determining the threshold condition.

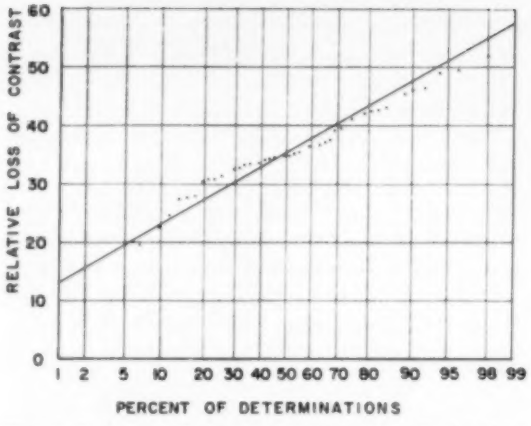

Figure 6. A typical set of determinations. Task: N.J.; footcandles: 70; location: A10; lighting system: general diffuse; azimuth: 0 degree.

(5) The task was then replaced in the test position over the photocell and five successive observations made of the transmission of the graded filter at threshold for the "no glare" condition. The average value was obtained and the threshold contrast factor calculated.

(6) The difference in these average threshold contrast factors was then expressed as a per cent, loss or gain, of the "no glare" threshold contrast factor. This constituted one determination.

(7) This procedure was repeated for each task, always going alternately from "glare" to "no glare" or in the reverse direction before changing tasks. This method was considered essential for subjective measurements of this nature in order to better ensure the same criterion for the "glare" and "no glare" conditions. A typical set of determinations of loss of contrast plotted on a probability scale is shown in Fig. 6.

Results

At least two and sometimes three observers took part for each condition tested. A test of significance was made between the means of each observer using Fisher's "t" distribution. All the results given showed a "t" value within the limits of Fisher's distribution for $P = 0.01$.

The results are given in tabular form to show the effect of various conditions on the contrast of the tasks. The "per cent loss" is the average loss in apparent contrast of the task in going from the "no glare" to the "glare" condition expressed as a percentage of the "no glare" contrast. The number of determinations "N" is also given and the

TABLE III—Loss in Contrast at Two Illumination Levels. Lighting System—General Diffuse; Location A10; Azimuth—0 Degree.

	30 Footcandles			70 Footcandles		
Task	Per Cent Loss	N*	Confidence Limits P=0.95	Per Cent Loss	N*	Confidence Limits P=0.95
A-1	17.6	47	±2.1	10.5	42	±4.1
A-2	7.7	47	±2.2	3.8	52	±2.5
NJ	20.2	47	±2.1	15.2	51	±2.6
8-11	23.6	47	±1.9	18.7	37	±3.5
LM	....	....	....	10.9	39	±3.6
6-2	19.4	47	±2.5	....	....	....
6-9	21.3	47	±2.4	....	....	....

*N = Number of determinations.

TABLE IV—Loss In Contrast at Two Illumination Levels. Lighting System—Direct; Location A10; Azimuth—0 Degree.

	30 Footcandles			55 Footcandles		
Task	Per Cent Loss	N*	Confidence Limits P=0.95	Per Cent Loss	N*	Confidence Limits P=0.95
A-1	16.6	38	±2.0	16.5	31	±2.9
A-2	8.2	46	±2.2	4.4	33	±3.2
N.J.	21.6	46	±1.9	20.6	33	±2.1
8-11	30.1	35	±2.4	24.1	33	±3.6
6-2	25.3	26	±2.2	24.7	33	±2.2
6-9	22.9	46	±2.5	19.0	33	±3.7

*N = Number of determinations.

TABLE V—Loss in Contrast at Two Illumination Levels. Lighting System—Luminous Indirect; Location A10; Azimuth—0 Degree.

	30 Footcandles			55 Footcandles		
Task	Per Cent Loss	N*	Confidence Limits P=0.95	Per Cent Loss	N*	Confidence Limits P=0.95
A-1	9.0	54	±2.5	8.8	39	±2.9
A-2	7.2	42	±2.9	4.6	39	±2.6
N.J.	10.8	75	±1.7	11.3	39	±2.2
8-11	15.7	46	±2.2	14.6	39	±2.6
6-2	9.9	54	±1.4	10.7	39	±2.1
6-9	10.8	38	±2.4	11.3	39	±2.7

*N = Number of determinations.

confidence limits of the loss in contrast are based on a probability of 95 per cent.

Tables III, IV and V show the effect of two different levels of illumination for the general-diffuse, direct and luminous indirect lighting systems respectively. The printed task LM was discarded in favor of two additional pencil tasks shortly after the tests were started. Some reduction in losses is indicated for the general-diffuse system in going from 30 to 70 footcandles. There is not much difference for the other two systems (Tables IV and V) in going from 30 to 55 footcandles.

Tables VI and VII show the effect of different lighting systems on the contrast of the tasks. In both tables lower losses are evident for the indirect lighting system. The printed task A-2 was quite diffuse in character, both ink and paper, which probably accounts for the little change in the losses for the different lighting systems.

Tables VIII and IX compare the losses at different locations in the room for the general-diffuse and luminous indirect systems. Position AB15, midway between the rows of luminaires, shows the least loss in contrast. In Table VIII, the greater losses at location B15 is probably less due to the lower footcandle level than because of the conditions and location in the room. The chalkboard on the right hand wall adjacent to B15 and the tackboard forming the upper wall were relatively low in reflection factor and for this reason there would not be much illumination reaching the task from the right hand side.

Table X shows the results for different azimuth positions at locations A10 and B15 for the general-

TABLE VI—Loss in Contrast for Different Lighting Systems. Illumination Level—30 Footcandles; Location A10, Azimuth—0 Degree.

	Direct			General Diffuse			Luminous Indirect		
Task	Per Cent Loss	N*	Confidence Limits P = 0.95	Per Cent Loss	N*	Confidence Limits P = 0.95	Per Cent Loss	N*	Confidence Limits P = 0.95
A-1	16.6	38	±2.0	17.6	47	±2.1	9.0	54	±2.5
A-2	8.2	46	±2.2	7.7	47	±2.2	7.2	42	±2.9
N.J.	21.6	46	±1.9	20.2	47	±2.1	10.8	75	±1.7
8-11	30.1	35	±2.4	23.6	47	±1.9	15.7	46	±2.2
6-2	25.3	26	±2.2	19.4	47	±2.5	9.9	54	±1.4
6-9	22.9	46	±2.5	21.3	47	±2.4	10.3	42	±2.6

*N = Number of determinations.

TABLE VII—Loss in Contrast for Different Lighting Systems. Illumination Level—As Shown; Location A10; Azimuth—0 Degree.

	Direct, 55 Footcandles			General Diffuse, 70 Footcandles			Luminous Indirect, 55 Footcandles		
Task	Per Cent Loss	N*	Confidence Limits P = 0.95	Per Cent Loss	N*	Confidence Limits P = 0.95	Per Cent Loss	N*	Confidence Limits P = 0.95
A-1	16.5	31	±2.9	10.5	42	±4.1	8.8	39	±2.9
A-2	4.4	33	±3.2	3.8	52	±2.5	4.6	39	±2.6
N.J.	20.6	36	±2.1	15.2	51	±2.6	11.3	39	±2.2
8-11	24.1	33	±3.6	18.7	37	±3.5	14.6	39	±2.6
6-2	24.7	33	±2.2				10.7	39	±2.1
6-9	19.0	33	±3.7				11.3	39	±2.7

*N = Number of determinations.

TABLE VIII—Loss in Contrast at Different Locations. Lighting System—General-Diffuse; Illumination Level—As Shown; Azimuth—0 Degree.

	Test Location A10			Test Location AB15			Test Location B15		
	70 Footcandles			70 Footcandles			55 Footcandles		
Task	Per Cent Loss	N*	Confidence Limits $P = 0.95$	Per Cent Loss	N*	Confidence Limits $P = 0.95$	Per Cent Loss	N*	Confidence Limits $P = 0.95$
A-1	10.5	42	±4.1	4.6	47	±2.2	15.5	41	±2.9
A-2	3.8	52	±2.5	1.5	47	±2.6	10.7	41	±2.3
N.J.	15.2	51	±2.6	4.5	47	±1.9	16.5	41	±2.0
8-11	18.7	37	±3.5	2.5	47	±2.3	25.9	41	±2.3
L.M.	10.9	39	±3.6	0.7	47	±3.2	12.8	41	±2.5

*N = Number of determinations.

TABLE IX—Loss in Contrast at Different Locations. Lighting System—Luminous Indirect; Illumination Level—As Noted; Azimuth—0 Degree.

	Illumination Level 30 Footcandles					
	Test Location A10			Test Location AB15		
Task	Per Cent Loss	N*	Confidence Limits P=0.95	Per Cent Loss	N*	Confidence Limits P=0.95
A-1	9.0	54	±2.5	4.5	48	±3.7
A-2	7.2	42	±2.9	5.4	48	±2.6
N.J.	10.8	75	±1.7	8.2	48	±2.7
8-11	15.7	46	±2.2	8.3	48	±2.8
6-2	9.9	54	±1.4	5.8	48	±1.6
6-9	10.3	42	±2.6	7.0	48	±2.6
	Illumination Level 55 Footcandles					
	Test Location A10			Test Location AB15		
Task	Per Cent Loss	N*	Confidence Limits P=0.95	Per Cent Loss	N*	Confidence Limits P=0.95
N.J.	11.3	39	±2.2	3.9	46	±1.9

*N = Number of determinations.

diffuse lighting system. The azimuth angle is the angle through which the visibility meter and observer were rotated with the task as the center. The zero-degree azimuth position is where the observer is facing directly to the front of the room. The results indicate no effect of azimuth position for the conditions tested.

Conclusions

The results indicate that a loss in apparent contrast of printed and pencil handwriting tasks can occur under certain lighting conditions. Further work is indicated in order to obtain more information that would permit the predetermination of losses for any given lighting situation and task characteristics.

It is regretted that time did not permit further tests in the present series that would have allowed more comparisons of the three lighting systems at all three room locations and at different azimuth angles.

The authors also feel that tests should be made for luminous ceiling systems in order to make the study more complete.

Acknowledgement

The authors received help from many sources and would especially like to acknowledge the assistance of the following: The Board of Education of Toronto for providing the equipment and facilities for the study, the Technical Advisory Committee on Light and Vision of the Illuminating Engineering Research Institute for their guidance and advice on the methods used in the tests and Miss Marion Currie for assistance in serving as an observer and for carrying out the calculations for significance tests and confidence limits.

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2. Cottrell, C. L.: "Measurement of Visibility," ILLUMINATING ENGINEERING, Vol. XLVI, No. 2, page 95 (February 1951).

3. Freund, Karl: "Design Characteristics of a Photo-Electric Brightness Meter," ILLUMINATING ENGINEERING, Vol. XLVIII, No. 10, page 524 (October 1953).

TABLE X—Loss in Contrast as Affected by Azimuth. Lighting System—General Diffuse; Location A10; Illumination Level—70 Footcandles.

	Test Location A10								
	Azimuth 0 Degree			Azimuth 22½ Degrees			Azimuth 45 Degrees		
Task	Per Cent Loss	N*	Confidence Limits P=0.95	Per Cent Loss	N*	Confidence Limits P=0.95	Per Cent Loss	N*	Confidence Limits P=0.95
N.J.	15.2	51	±2.6	14.2	48	±2.5	14.3	48	±1.5
	Test Location AB15								
N.J.	4.5	47	±1.9	4.7	54	±1.9	.....	....	....

*N = Number of determinations.

The Effect of
Specular Reflection on Visibility

Part III--New Charts for Brightness Contrast Calculations

By ISAAC GOODBAR

Introduction

Studies of loss of contrast due to reflections of overhead lighting units (or local lighting units) in the details and background of reading, writing and drafting tasks have advanced to the point where the losses are now known to be a serious factor in visibility. The results are demonstrating that quality of lighting in terms of candlepower distribution from luminaires can strongly influence the actual net contrast of the task and therefore the amount of light necessary to see it. Since each system of lighting will produce its own contrast of these tasks in the field, it becomes necessary to predict the losses of that which occur and arrive at the contrast of a given task at a given point in a room interior. This paper develops methods of predicting the contrast of a task and, therefore, the losses under different lighting systems.

Professor Finch has measured, as part of extensive visibility studies, the brightness of many tasks and their backgrounds.[1] From his photometric measurements, Professor Finch has determined the "Brightness Factors" defined as the value by which the illumination normal to the surface has to be multiplied in order to obtain the brightness as seen in the particular direction.

Every surface has its own particular characteristic pattern of brightness factors depending upon the material, texture, spectral absorptance and reflectance, and certain intangible quantities characteristically referred to as sheen or gloss. The brightness values under consideration were obtained and plotted for several materials, always viewed at an angle of twenty-five degrees from the normal, as a function of the vertical and azimuth angles of the source. Figs. 1 and 2 show these results for Sample 8-11 C which was a schoolboy's handwriting on white matte paper similar to those shown in Fig. 3.

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While using these results to compute brightness contrasts to be expected in actual rooms with different lighting layouts, the author thought that other methods of representing Professor Finch's results, different from the ones shown in Figs. 1 and 2, might considerably simplify the required computations and, besides, clarify some of the concepts involved, making possible the design of lighting taking into account possible losses of contrast due to specular reflections. It is important to note that the idea of iso-brightness charts to facilitate incremental brightness calculations occurred at the same time to Professor E. M. Strong. The Illuminating Engineering Research Institute assigned to the author the task of preparing the new charts presented in this paper.

Computation of Brightness Contrasts by Means of Professor Finch's Original Curves (Figs. 1 and 2).

The brightness contrast of a certain task is defined as the ratio of the brightness difference (between the task and its surrounding) to the background brightness. To compute the brightness contrast to be expected under a specific lighting layout it is, therefore, necessary to divide the layout into units small enough for the brightness factor to remain constant within each of them; then, for each of these units, it is necessary to proceed as follows:

(1) Determine by computation the altitude angle and azimuth of the straight lines joining the task to the unit considered. Find the candlepower in that direction.

(2) Find from or by interpolation between the curves of Fig. 1 the brightness factor of the detail of the tasks for the angles found in Step 1.

(3) Compute the normal illumination due to the particular unit (point-by-point method).

(4) Multiply the normal illumination by the brightness factor to obtain the brightness contribution from the unit considered.

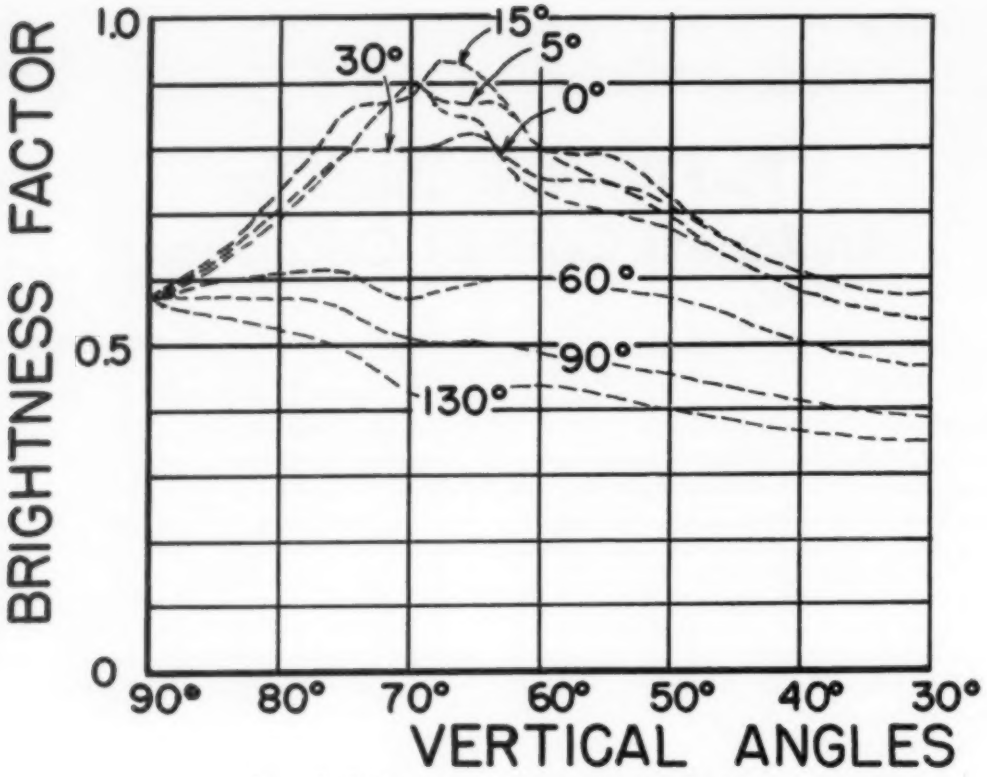


Figure 1. Brightness factors for pencil lines. (Finch)

(5) Add all the previous results to obtain the total task detail brightness due to the entire lighting layout.

(6) Repeat the whole procedure for the task background brightness.

(7) Find the difference between the task detail brightness and the background brightness and divide this difference by the background brightness to obtain the resultant contrast.

For most lighting layouts the above procedure results, in practice, in rather extensive computations.

New Charts to Represent The Reflectance Characteristics

Assuming the task A on a horizontal plane, α, another horizontal plane, β at a distance, a, over it is considered. A source, S, on this plane β will be considered and it will be assumed that it emits a candlepower, I_θ, in the direction of A (Fig. 4), that is, at an angle θ with the vertical; then the horizontal illumination E_i will be:

$$E_i = \frac{I_\theta}{a^2} \sin^3\theta \qquad (1)$$

Multiplying this by the brightness factor b_{iT} of the task detail, the brightness contribution ΔB_{iT} due to the source (S_i) will be obtained:

$$\Delta B_{iT} = \frac{I_\theta b_{iT}}{a^2} \sin^3\theta \qquad (2)$$

Formula 2 can be written:

$$\Delta B_{iT} = \frac{I_\theta}{a^2} (b_{iT} \sin^3\theta) \qquad (3)$$

Since b_{iT} is a function of the azimuth and vertical angles, θ expressed graphically in Fig. 1, and these angles can be expressed themselves as functions of the coordinates, x, y, in a system of coordinate axes passing through the point A' which is the vertical projection on the plane, β, of the point A, formula (3) can be written:

$$\Delta B_{iT} = \frac{I_\theta}{a^2} f_T (x_i, y_i) \qquad (4)$$

If all the n sources S_i are on the same horizontal plane, β, the total task brightness will be:

$$B_T = \frac{1}{a^2} \sum_{i=1}^{n} f_T (x_i, y_i) I_\theta \qquad (5)$$

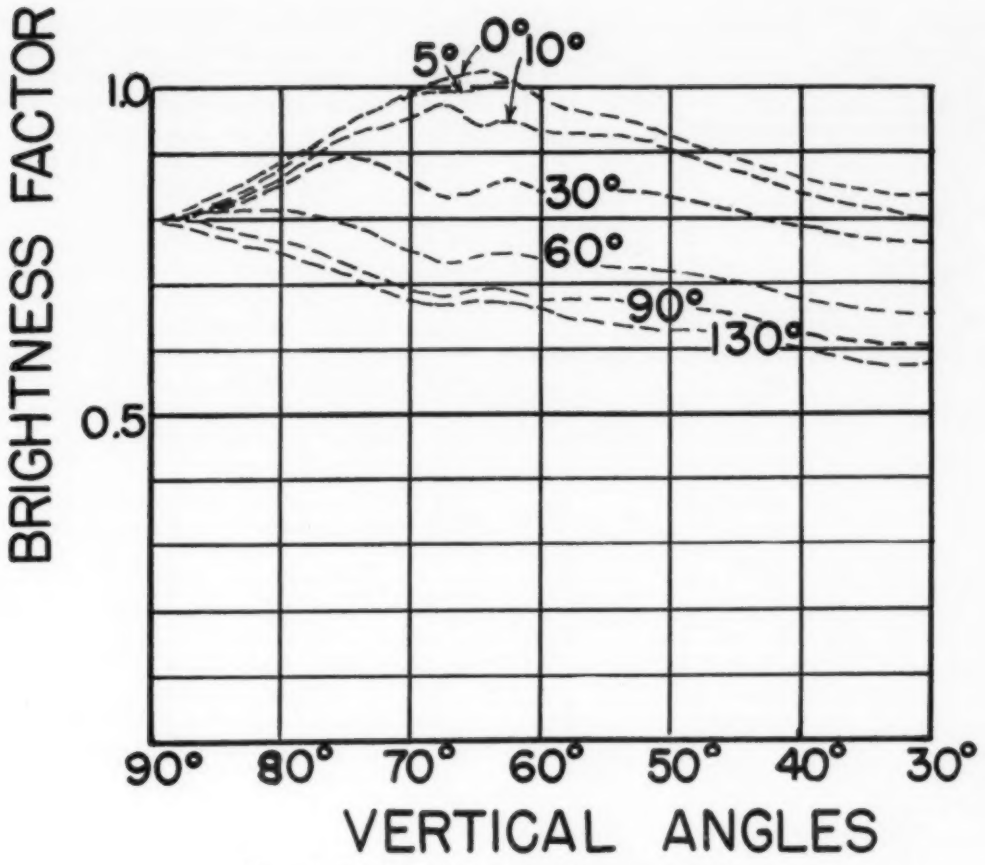


Figure 2. Brightness factors for white paper. (Finch)

Similarly the total background brightness is:

$$B_B = \frac{1}{a^2} \sum_{i=1}^{n} f_B\,(x_i, y_i)\; I_\theta \qquad (6)$$

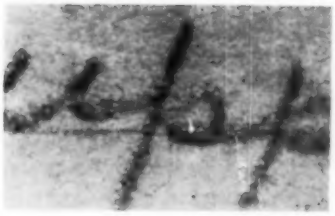
Subtracting (6) from (5) and dividing by (6), the brightness contrast is obtained:

$$C = \frac{B_T - B_B}{B_B} = \frac{\sum_{i=1}^{n} f_T(x_i,y_i) I_\theta - \sum_{i=1}^{n} f_B(x_i,y_i) I_\theta}{\sum_{i=1}^{n} f_B(x_i,y_i) I_\theta} \qquad (7)$$

which shows that the brightness contrast is entirely independent of the height a (Fig. 4). Therefore the functions

$$f_T\,(x, y) \text{ and } f_B\,(x, y) \qquad (8) \text{ and } (9)$$

can be plotted in any horizontal plane over a. These functions (8) and (9) will be called *incremental candlepower coefficients* for the task and for the background. By equating (8) to different constants it is possible to plot on a plane, β, a set of curves for each of which the incremental candlepower coefficient for the task brightness will remain constant. This was done in Fig. 5. Also by equat-



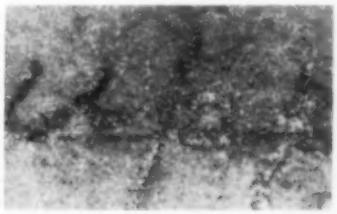


Figure 3. (left) 90 degrees incident light; 115 degrees viewing angle (0 degrees to normal); (right) 65 degrees incident light, 115 degrees viewing angle (25 degrees to normal). (Sinch)

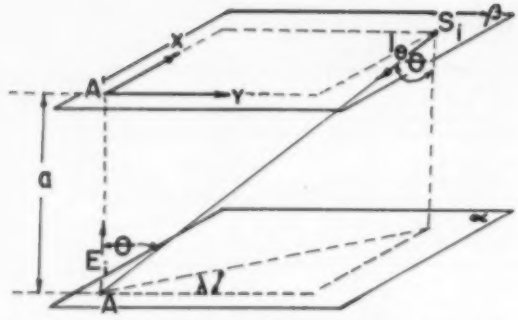


Figure 4. α **plane of the task;** β **horizontal plane of the source.**

ing (9) to different constants a series of curves can be plotted for each of which the incremental candlepower coefficient for the background remains constant. It is assumed then that this series of curves is plotted on an arbitrary plane, β, at a distance a over the task plane, α, and that it is desired to obtain the brightness contrast due to a group of luminaires located all in a certain horizontal plane γ at a distance h over the task plane α (Fig. 7). Equations (3) and (4) show that the incremental candlepower coefficients depend only upon the azimuth and altitude angles. Therefore if, taking as a center of projection, the point A (task), all the luminaires, S_i, located on the plane, γ, are projected into the arbitrarily chosen plane, β, a system of lighting fixtures will be obtained

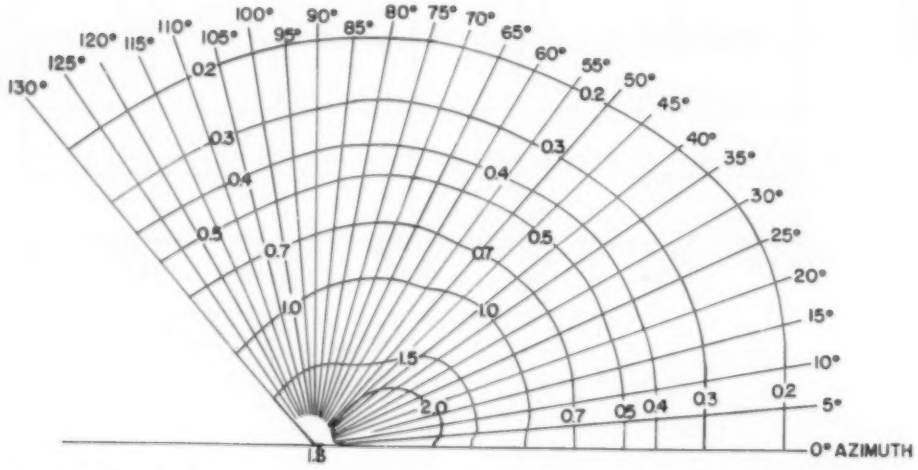


Figure 5. New chart giving *incremental candlepower coefficients* for pencil lines (Sample 8-11).

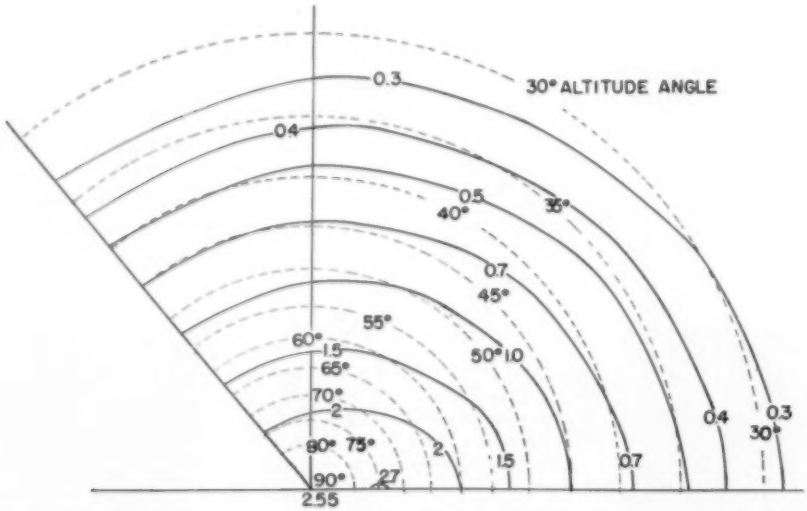


Figure 6. New chart giving *incremental candlepower coefficients* for white paper (Sample 8-11).

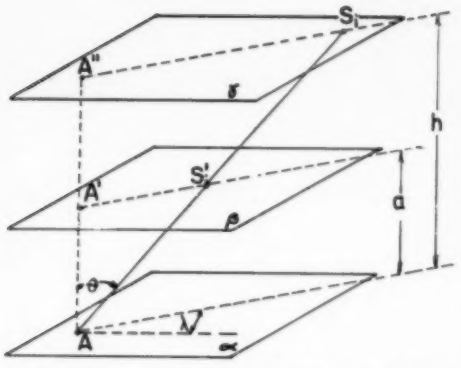


Figure 7 (above). α plane of the task; β plane of charts (Figs. 5 and 6); γ horizontal plane through the source.

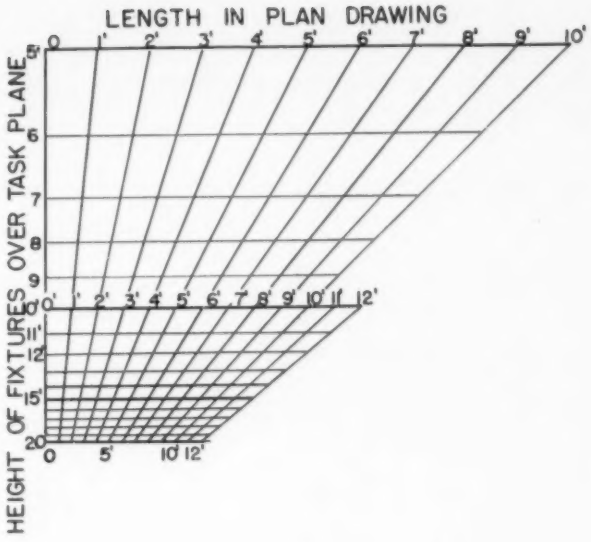


Figure 8 (right). Lengths in plan drawing corresponding to feet, for different mounting heights.

which will produce exactly the same brightness contrast, in accordance with formula (7), as the original system, S_0, did. The plane, β, is actually the plane of Figs. 5 and 6, and this projection can actually be done, in practice, by simply drawing a ceiling plan on the plane of any of these figures, in a scale determined in accordance with the following formula:

$$\frac{\text{Real dimension}}{\text{Drawn dimension}} = \frac{h}{a} \qquad (10)$$

which can be deduced immediately from Fig. 7, by similarity of triangles. Fig. 8 has been drawn so as to give directly the lengths in the drawing corresponding to feet for different heights h of the luminaires over the working plane. Therefore, in order to obtain the brightness contrast due to any group of luminaires located on the same horizontal plane, by means of the charts of Figs. 4 and 5, all that has to be done is:

(1) Draw the lighting layout on a tracing paper in a scale determined by means of Fig. 8.

(2) Apply this drawing (Fig. 9) over the chart of Fig. 5 and read the incremental candlepower coefficients for the different lighting units (Fig. 10). At the same time it is possible to read directly on this chart the azimuth angles and, by means of Fig. 6, the altitude angles, required to obtain the candlepower.

(3) By multiplying the candlepower by the incremental candlepower coefficients, certain increments are obtained for the brightness on the task, adding all these increments a value proportional to the brightness on the task is obtained.

(4) Lay the plan drawing (Fig. 9) over Fig. 6 and read (Fig. 11) the incremental candlepower coefficients for the background in that figure (which also gives the altitude angles), multiply these values by the candlepower values already obtained for each unit and obtain the brightness increments.

(5) Add all the background brightness increments to obtain a figure proportional to the background brightness.

(6) Subtract the figure that was proportional to the task brightness (Step 3) from the one for the background brightness and divide by this last one to obtain, in accordance with formula (7), the brightness contrast.

As it can be seen, this procedure is shorter than the one first mentioned consisting of the direct use of Figs. 1 and 2; besides, it is easy to visualize the effect of locating units in definite positions, which may help greatly in laying out the lighting plan. Figs. 10 and 11 illustrate the result of applying the drawn plan over the charts of Figs. 4 and 5 respectively. If it should happen that many computations of this type have to be performed with the same type of luminaire, other types of charts different from the ones represented in Figs. 5 and 6 may be more convenient. These may be obtained by plotting, instead of formulas (8) and (9) equated to different constants, the following, also equated to different constants:

$$\phi_T\ (x, y) = I_\theta b_T \sin^3\theta \qquad (11)$$

$$\phi_B\ (x, y) = I_\theta b_B \sin^3\theta \qquad (12)$$

If such charts were plotted, all that would be necessary to obtain the brightness contrast would be to lay the plan drawing in a proper scale over one of these charts, add directly the readings for the different luminaires, and again lay the plan over the other chart, add the readings on this sec-

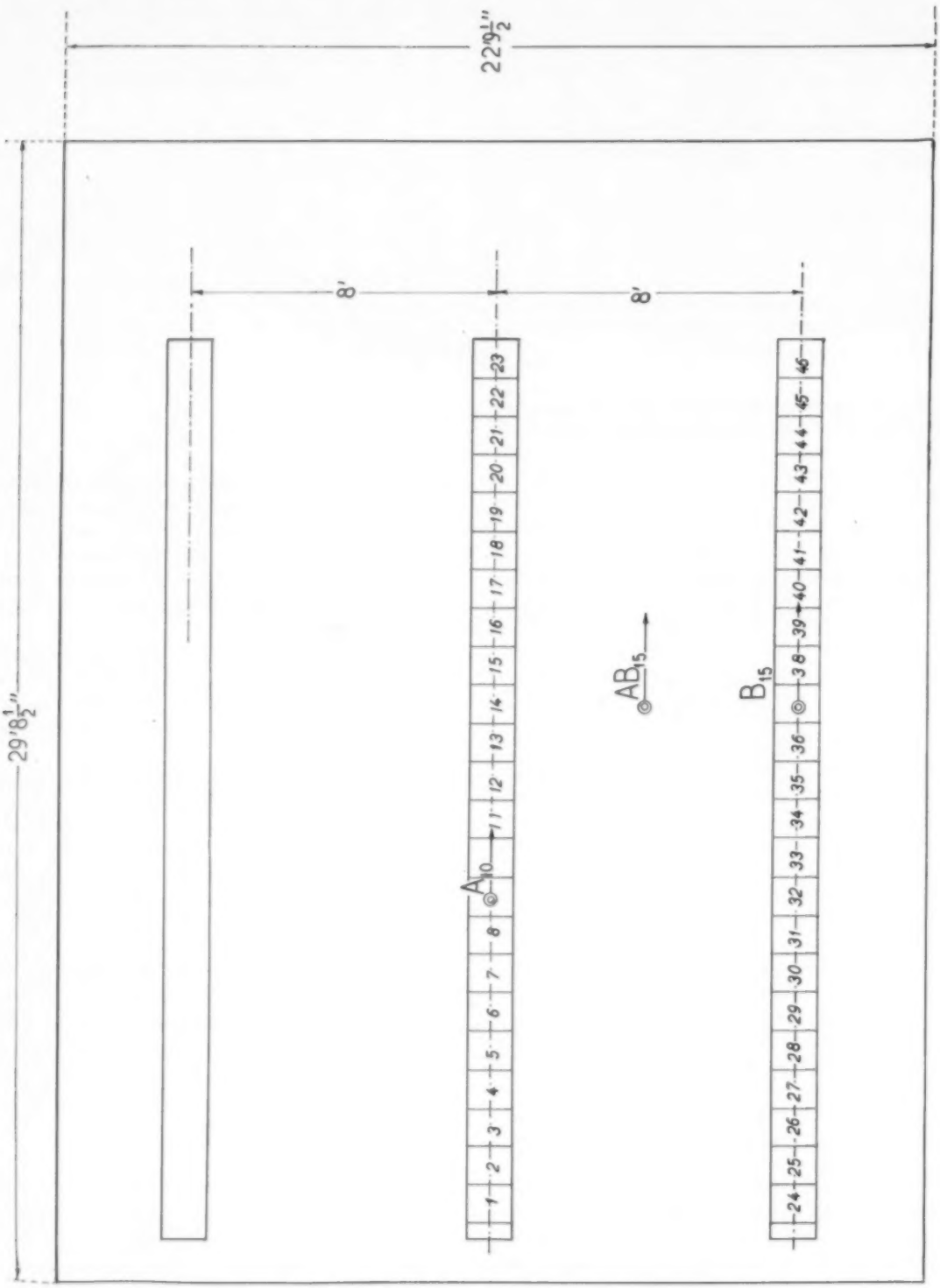


Figure 9. Layout in Ogden School, Toronto, Ontario.

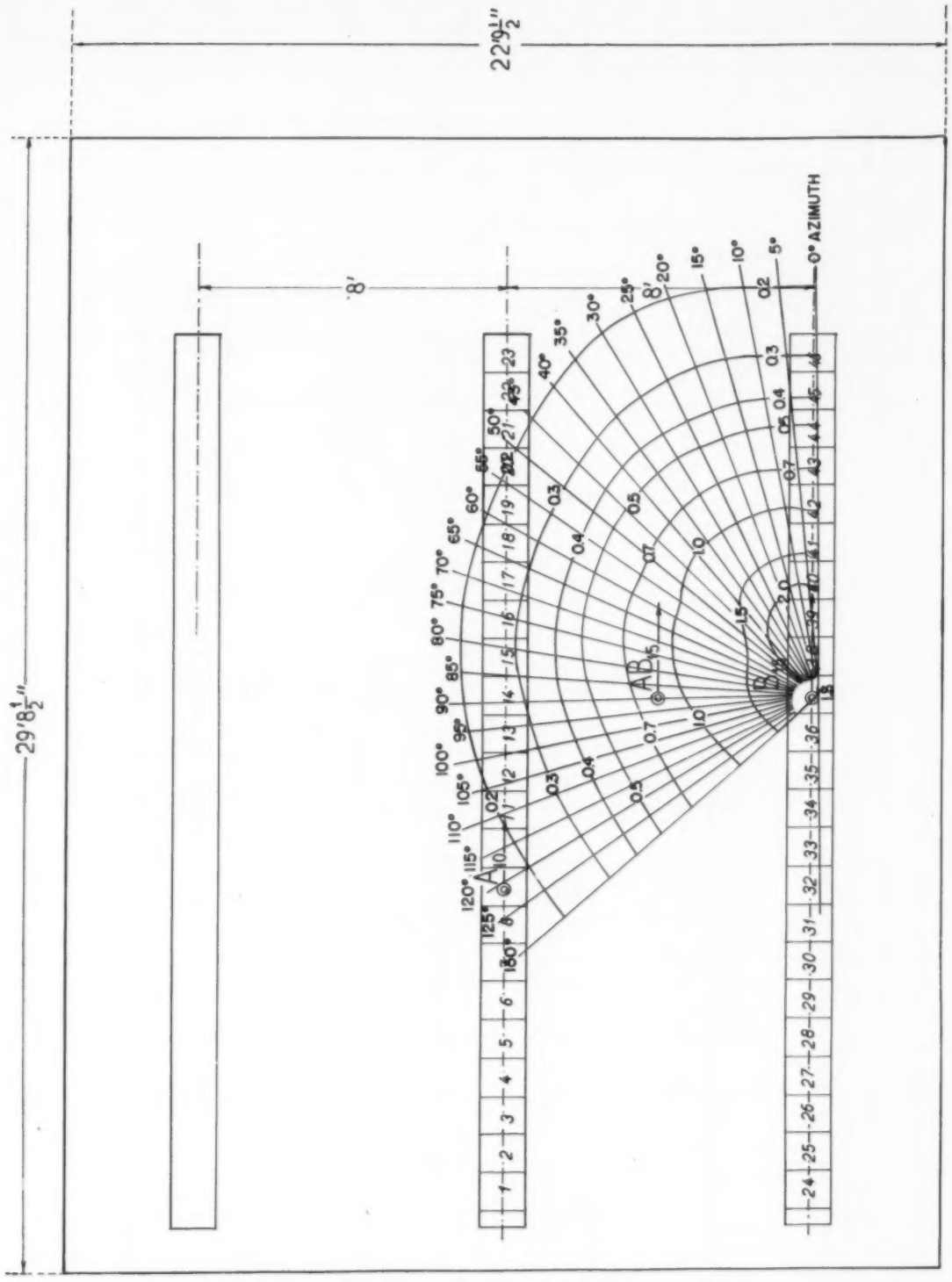


Figure 10. Obtained from the application of Fig. 9 over Fig. 5.

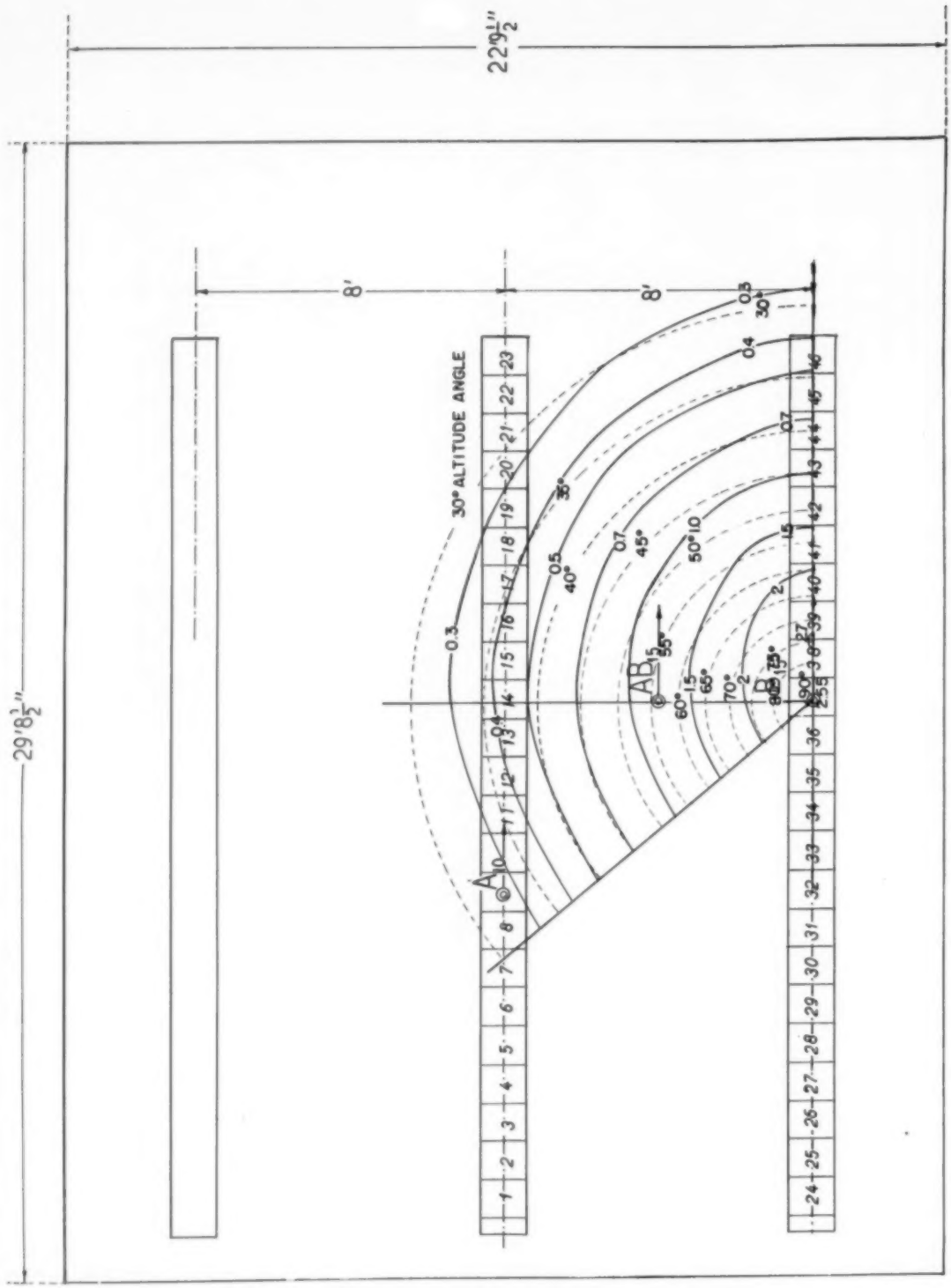


Figure 11. Obtained from the application of Fig. 9 over Fig. 6.

Figure 12 (right). Set of curves to simplify the plotting of the new charts. To be laid over Figs. 1 and 2.

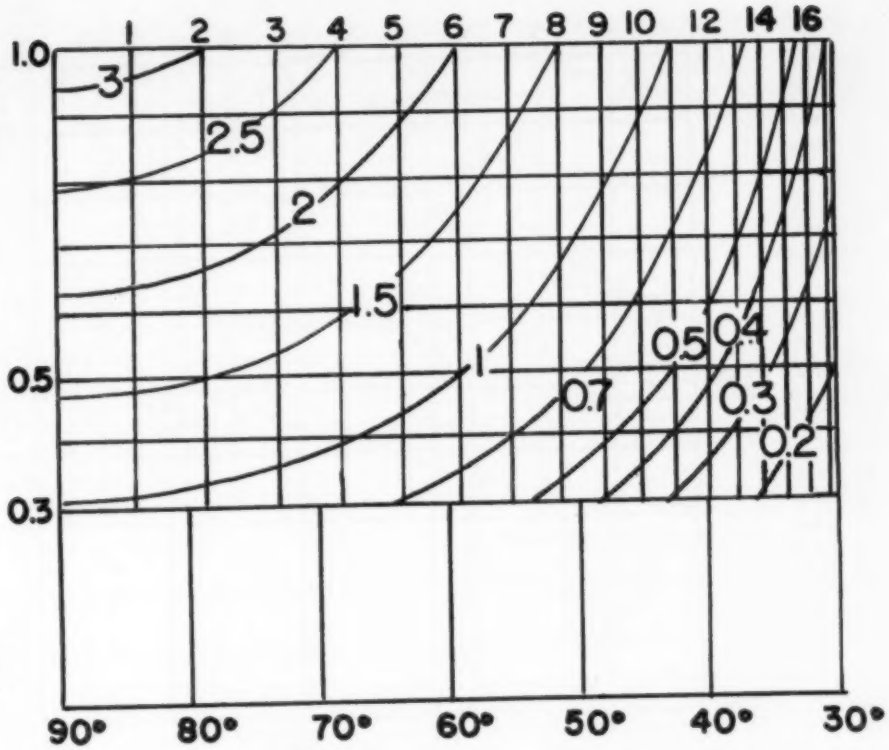
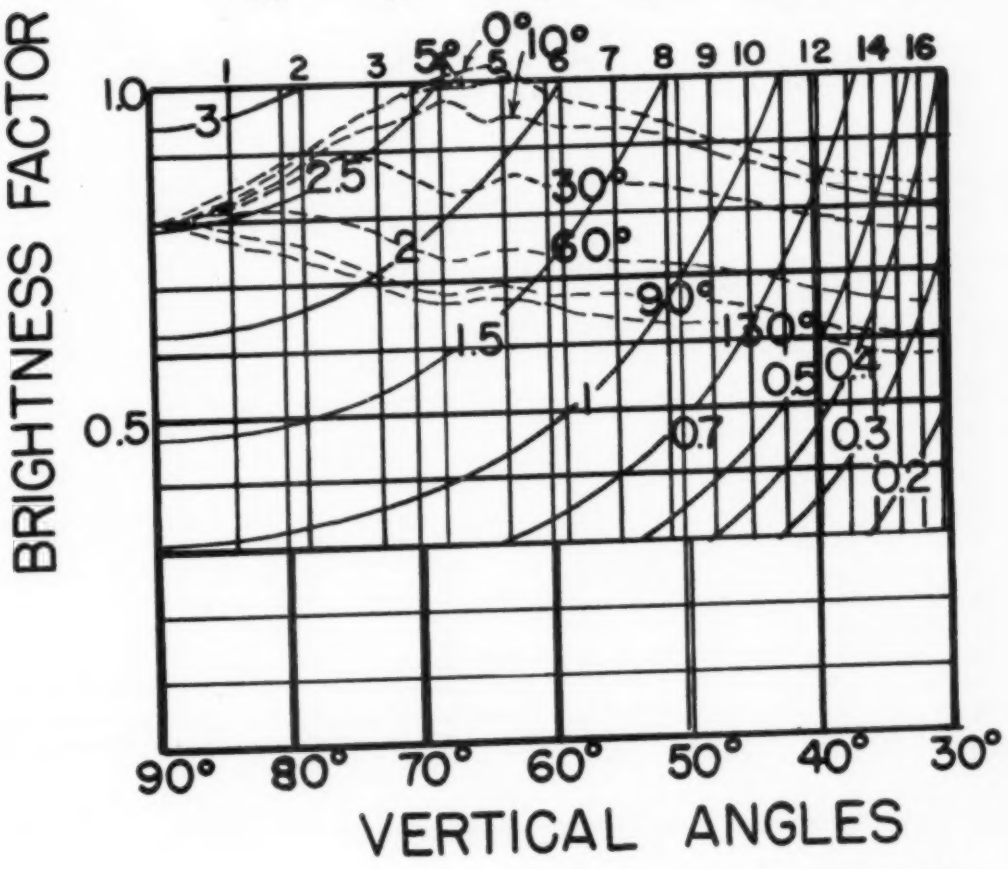


Figure 13 (below). Obtained from laying Fig. 12 over Fig. 1.



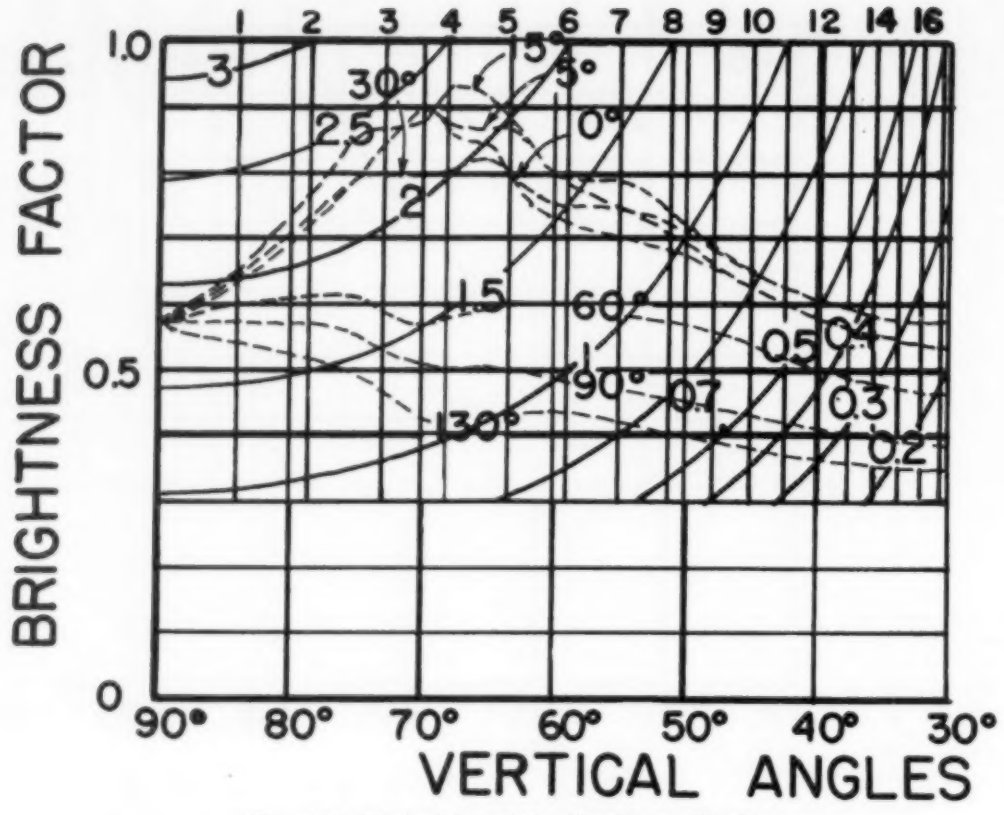


Figure 14. Obtained from laying Fig. 12 over Fig. 2.

ond chart, and then, from these two totals, obtain the brightness contrast as usual, in accordance with formula (7). In time, manufacturers may supply such charts for standard tasks and backgrounds just as at present they supply candlepower distribution and brightness curves.

To obtain the brightness contrast due to luminous ceilings, one square foot at one footlambert brightness may be considered as a luminaire emitting in every direction a candlepower:

$$\frac{1}{\pi}\sin\theta \qquad (13)$$

Special charts for this situation are advisable. Readings for every square foot, in these charts, must be multiplied by the brightness of the surface, as seen from the task.

The readings in these charts will be called "incremental brightness coefficients."

Appendix A

A simplified method to draw the new charts for incremental candlepower contribution, when the set of curves like those of Figs. 1 and 2 are available, will be described in this appendix.

Tests like those performed by Professor Finch will, of course, continue and it is expected that more data for many other types of tasks and backgrounds will be available and will be probably directly plotted as shown in Figs. 1 and 2. A simplified method enabling to pass quickly from this form of representation (Figs. 1 and 2) to the new charts (Figs. 5 and 6), may therefore be very helpful. Let a source emitting unity candlepower in every direction be assumed; then the brightness increment due to this source when it is located at an altitude angle θ (Fig. 3) will be:

$$\Delta B = \frac{b}{a^2}\sin^3\theta \qquad (14)$$

where b is the brightness factor as plotted in Figs. 1 and 2. Plotting a set of curves (Fig. 12)

$$\frac{K}{\sin^3\theta} \qquad (15)$$

for different values of K and assigning to them values proportional to K; at the points where any of these curves intersect one of the curves of Figs. 1 or 2, over which Fig. 12 is to be laid, the incremental candlepower coefficient will be proportional to the designation of the curve. This will happen for an altitude angle that can be read on the same vertical and for an azimuth angle corresponding to the curve in question of Fig. 1 or 2. In Fig. 12 there is also, on top,

a scale showing the distance on the plane B, that is the plane of Figs. 5 or 6 in the scale shown in Fig. 15, that corresponds to the different vertical angles θ in degrees.

Therefore, to plot a complete chart like the ones of Figs. 5 or 6 it is necessary to proceed as follows:

(1) Draw straight lines on either Fig. 5 or 6 for the different azimuth angles.

(2) Lay Fig. 12 over the graphical representation of the brightness factor (Fig. 1 or 2). Figs. 13 and 14 show the result of such superposition.

(3) Whenever each of the curves of the family drawn in Fig. 12 intersects a brightness factor curve for a particular azimuth mark, in Figs. 5 or 6, the value of the curve in Fig. 12 at the distance, in the scale in Fig. 15, from the origin, shown on the top horizontal scale and read over the point of intersection. This point will be marked on the line corresponding to the azimuth in question.

(4) Join with a smooth curve the points having the same values on the different azimuth lines.

Fig. 13 represents the result of applying Fig. 12 over Fig. 1. Fig. 12 as published can be used for any other set of brightness factor curves drawn to the same scale of Figs. 1 or 2. Fig. 14 is the result of applying Fig. 12 over Fig 2; it will produce the chart of Fig. 6.

Appendix B

All the preceding considerations apply to cases where all the lighting fixtures are on the same horizontal plane. This is, of course, the situation most often encountered. However, quite often a situation where the light reaches the task and environment from more than one horizontal plane is also likely to be encountered. For instance, in a semi indirect lighting system part of the light comes from the luminaires, located all on the same horizontal plane, while another part comes from the ceiling which is also located on a horizontal plane, but on a horizontal plane different from the one containing the centers of the luminaires. To obtain the brightness contrast in this case, all that has to be done is to prepare two ceiling plans: one for the luminaires drawn to a scale corresponding to the height of them, and the other for the ceiling in a scale, also obtained from Fig. 7, for the ceiling height. By the procedure described, brightness contrast due to the ceiling alone and due to the luminaires alone will be readily obtained. All that has to be remembered to obtain the combined brightness contrast is that the brightness contribution, being proportional to the horizontal illumination, is inversely proportional to the square of the distance, or to the square of the height. Therefore, the total task brightness will be the brightness contribution due to the luminaires plus the brightness contribution due to the ceiling multiplied by the square of the height of the luminaires and divided by the square of the ceiling height. The background brightness will be similarly equal to the contribution due to the luminaires plus the contribution due to the ceiling multiplied by a similar factor. Determining in this way the task and background brightness the combined brightness contrast will be obtained as usual, in accordance with formula (7).

Of course, as several times mentioned, these brightnesses obtained are not true brightnesses but are proportional to true brightnesses, giving, therefore, true brightness contrasts. The results would have been exactly the same if the luminaire contribution had been multiplied by the square of the ceiling height divided by the square of the luminaire height and the ceiling contribution taken as originally obtained.

Figure 15. Scale to be used when drawing new incremental coefficients charts, as explained in Appendix A.

IES Lighting Data Sheets and The New Footcandle Recommendations

In June 1958, a new set of footcandle recommendations was adopted by the Illuminating Engineering Society. The new values, in most cases, are considerably higher than the superseded ones. This means that many of the IES Lighting Data Sheets published before June 1958 report installations that do not meet present IES recommended practice, as to *footcandles on the task*.

It should be recognized, however, that the footcandle level provided is only one of several considerations that determine the quality and all-around adequacy of an installation, and its suitability for recording in an IES Lighting Data Sheet. Visual comfort, brightness ratios and the inherent appropriateness of the lighting system to the lighting application are equally important factors.

It is suggested, therefore, that IES Lighting Data Sheets issued before June 1958 may still be used with confidence as a guide to good lighting practice so far as lighting techniques are concerned. To determine whether the footcandle values indicated meet present recommendations, consult the footcandle tables published in the August 1958 issue of Illuminating Engineering and supplemented in the February 1959 issue, or in the Third Edition, *IES Lighting Handbook*.

Subcommittee on Lighting Data Sheets
Publications Committee

The Estimation of Magnitude of Glare Sensation

By R. G. HOPKINSON
R. C. BRADLEY

Attempts have been made to estimate the magnitude of the sensation of discomfort from glare. Hitherto all such attempts have been avoided in the Building Research Station's work, but recent success with mental estimations of apparent brightness suggested that glare discomfort magnitude also might be evaluated numerically, provided subjects unversed in other methods of sensation estimation were employed. The results are consistent and promising. The concepts of "twice as glaring," "ten times as glaring," "one-half as glaring," etc. correlate with both source brightness and surround brightness in a way which is consistent with the relations established with the multiple-criterion technique.

Introduction

Sensations of pain or discomfort are difficult to describe specifically, as clinicians well know, and still more difficult to evaluate quantitatively. Wolff and Wolf[1] established a scale of pain based on twenty-two discriminable increments of pain from threshold to pain of maximal intensity. Two such steps were defined as one "dol," a scale on which a severe headache would be rated at about four dols. Most workers, however, have been content to assess the magnitude of pain in qualitative or comparative terms only.

This has also been the attitude so far taken up in the Building Research Station's work on glare discomfort. Knowing the manifold pitfalls of all sensation-magnitude estimation and the inevitable criticisms of any attempts to evaluate sensations quantitatively (criticisms which would have diverted attention from the main purpose of the work), it was our deliberate policy to avoid any translation of the multiple-criterion scale[2] into a numerical scale.

With the greater use of the glare-discomfort data, it was inevitable that engineers and users would ask, as they have over noise discomfort problems, what has to be done to an installation to, for example, "reduce the glare to one-half as bad as it is now?" Some psychologists would hold that such a question is meaningless, but the fact that it has been answered to the satisfaction of very many others, especially in the case of noise, would suggest that the objections arise from prejudice rather than evidence. The work of S. S. Stevens of Harvard University, for example, has shown that consistent and reliable estimates of sensation magnitude are possible in a wide range of modalities, and that they are of real engineering value.

It will be appreciated that this question, although often asked by the lighting engineer, has never been answered by the existing experimental work. The magnitude of glare discomfort sensation has been appraised either, as in Guth's work in the United States, by a "sensation index" based on the probability of a given sensation (*e.g.*, the BCD, or "borderline between comfort and discomfort") being experienced, or, as in the Building Research Station work, by a verbal scale of multiple criteria which are specific but not scalar. Recent experimental work on the numerical estimation of apparent brightness magnitude, following discussions with Stevens of Harvard, led to a feeling that "naive" observers who had not been trained in the multiple criterion technique might be able to make such numerical estimations. (Experience has shown that non-scientific people can make these judgments more readily than those trained in the mathematical sciences.)

The Experiments

The experiment on glare magnitude judgment had to be designed so there could be no doubt that it was glare that was being judged and not brightness. The most satisfactory procedure would have been to adjust the *size* of the source, since it is known that glare is dependent on source size, whereas ap-

AUTHORS: Building Research Station, Garston, Herts, England and Cornell University, Ithaca, N. Y., respectively. This paper became available through Research Project #59 of the Illuminating Engineering Research Institute.

parent brightness is not. However, equipment for making this adjustment was not available, although we intend to perform this experiment eventually. It was decided, instead, to take advantage of the fact that glare is a function not only of the source brightness, but also of the contrast of this brightness with the surroundings.[3,4] If the surround brightness is *lowered*, the degree of glare will *increase*. It was, therefore, hoped that the subjects would be foiled by the fact that a *reduction* in the physical parameter gave an *increase* in the sensation they were being asked to judge, and so would avoid making their judgments on brightness. The reduction of the surround brightness would, however, certainly cause an increase in the *apparent brightness* of the source, and there could be no guarantee that this would not influence the judgment of glare magnitude. (The results suggest, however, that it did not.)

The subjects were shown a scene representing a school classroom in which two typical light fittings could be seen. Both the brightness of these light sources and the brightness of the surroundings could be independently varied by an optical system described elsewhere.[3] The conditions were set at levels not far removed from a typical rather glaring lighting installation. The source brightness was actually 1,000 footlamberts and the surrounding brightness 0.25 footlambert. These conditions, experienced by the average subject, gave rise to glare which is distinctly uncomfortable, mid-way between "just uncomfortable" and "just intolerable" on the multiple criterion scale. The subject was shown these conditions by the experimenter and was given control of the surrounding brightness which, initially, he was permitted to vary to obtain a feel for the task. After return to base conditions by the experimenter, the subject, taking as much time as he desired, was asked to *reduce* the surrounding brightness until the glare from the source was "twice as uncomfortable" as previously. The purpose of giving him control of the surrounding brightness was to try to ensure that he would not make the judgment of "twiceness" on the basis of apparent brightness, as might have happened if he had been given control of the source brightness. After he had made this judgment, the conditions were returned to the original by the experimenter, and he was asked to adjust again the surround brightness until the glare was "ten times as uncomfortable." The same procedure was repeated for one-half, and one-tenth as uncomfortable. As an empirical check, the subject was then given control of the source brightness, and data were taken using the same standard conditions and discomfort conditions; judgments of glare magnitude now being made with a constant surround brightness. In all, 12 different subjects made observations, but of these 12, one was rejected for unwillingness and one for admitted inability to perform the experiment. Two further subjects made subjective evaluations, but as these were contradictory to all previous experiences (the subjects said that the glare was reduced when the surround brightness was lowered), the observations were not included in the final analysis. One other observer made only a partial set of observations. All of these observations were recorded but have not been included in the analysis. The data are shown in Tables I and II and illustrated in Figs. 1 and 2.

Fig. 1, illustrating the data of Table I, relates the judgments made by varying surround brightness; Fig. 2, the data of Table II, and the judgments made by varying source brightness.

The data of Fig. 1 show a rather wide variance but a fairly good plot through the medians of the observations is possible. It will be remembered in this case that the glare increased while the physical variable (surround brightness) decreased.

The data of Fig. 2 are rather more consistent in

TABLE I — Variation of Log Surround Brightness, Log B_b, with Magnitude of Glare Discomfort Sensation, G_D, at a Constant Source Brightness of 1000 fL and a Standard Condition Surround Brightness of 0.25 fL at which the Magnitude of Glare Discomfort Sensation is X.

	Log B_b in Log fL for Various Magnitudes of Glare Discomfort Sensation G_D				
Observer	10X	2X	X	X/2	X/10
a	−1.45	− .95	− .60	− .27	+ .20
b	−2.50	−1.60	− .60	+ .15	+1.24
c	−2.30	−1.00	− .60	− .28	+ .05
d	−1.50	− .90	− .60	− .15	+ .38
e	−2.40	−1.38	− .60	− .33	+ .10
f	−2.50	−1.30	− .60	− .06	+ .48
g	−1.40	−1.10	− .60	− .32	+ .53

TABLE II — Variation of Log Source Brightness, Log B_s, with Magnitude of Glare Discomfort Sensation, G_D, at a Constant Surround Brightness of 0.25 fL and a Standard Condition Source Brightness of 1000 fL at which the Magnitude of Glare Discomfort Sensation is X.

	Log B_s in Log fL for Various Magnitudes of Glare Discomfort Sensation G_D				
Observer	10X	2X	X	X/2	X/10
a	+3.83	+3.30	+3.00	+2.75	+2.30
b	+4.04	+3.41	+3.00	+2.63	+2.27
c	+3.44	+3.31	+3.00	+2.54	+2.33
d	+3.65	+3.34	+3.00	+2.54	+2.19
e	+3.55	+3.24	+3.00	+2.68	+1.70
f	+4.04	+3.54	+3.00	+2.57	+2.30
g	+3.51	+3.30	+3.30	+2.76	+2.28

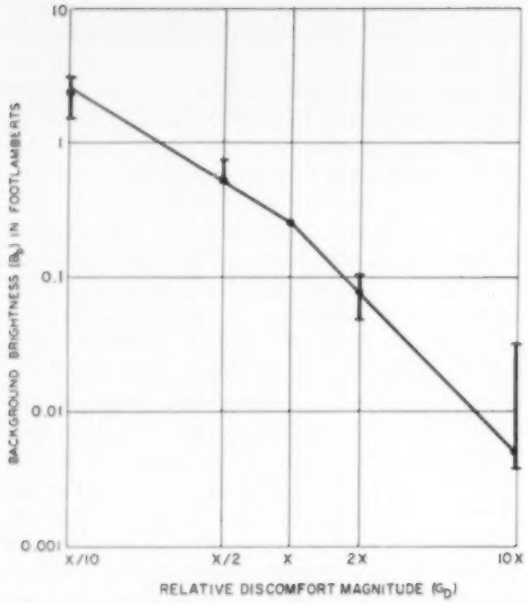


Figure 1. Estimates of magnitude of glare sensation with variation of surround brightness. Source brightness 1000 footlamberts. Medians and interquartile ranges.

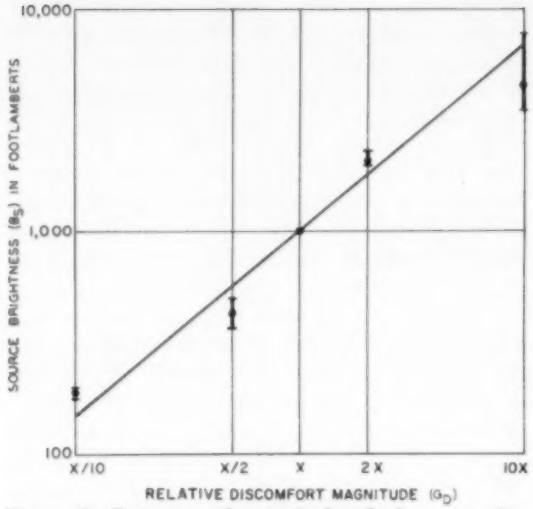


Figure 2. Estimates of magnitude of glare sensation with variation of source brightness. Surround brightness 0.25 footlambert. Medians and interquartile ranges.

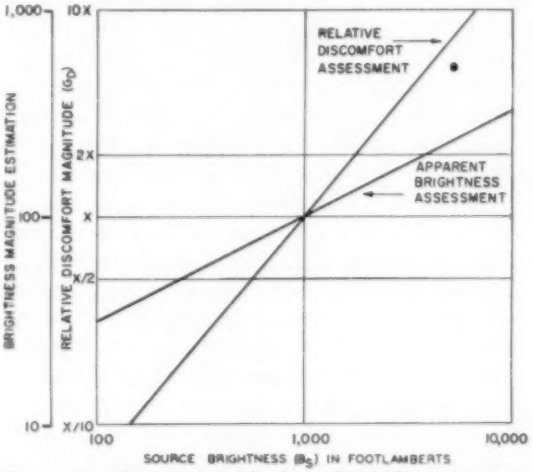


Figure 3. Comparison of glare discomfort estimates with apparent brightness data for surround brightness of 0.25 footlamberts.

that the variance is less. Again, a good plot can be made through the median points. It is of some interest that the curve for apparent brightness magnitude for the appropriate adaptation conditions, derived from the data of Hopkinson,[5] when plotted on the same scale, is quite distinctly different from the regression line through the glare judgment data. There is, therefore, some reason for confidence that the judgments were indeed based on glare discomfort sensation and not on apparent brightness sensation (Fig. 3).

It is possible now to relate these magnitude judgments with the steps on the multiple criterion scale (see Appendix). On the average, a step of one criterion appears to be equal to about "three times" on the magnitude scale (See appendix).

It is also of interest that the correlations from Fig. 1 and Fig. 2 are mutually consistent with one another and with the exponents in the Building Research Station glare formula (see Appendix). This gives some confidence that the exponents of the Building Research Station formula are valid for the conditions of the experiment, whether the judgments are made by a multiple criterion or by a sensation magnitude method.

The results of these glare-magnitude judgment experiments may be of some importance to lighting engineering because they permit a tentative answer to be made, for the first time, to the question of the degree of change which it is necessary to make in an interior lighting installation in order to make a quantitative improvement in the glare. It would be desirable to supplement the data by observations from a larger number of subjects, but it is probable that sufficient information has already been obtained to give fair appraisal of the problem.

It must be appreciated, nevertheless, that it is still not understood exactly what is meant by sensation magnitude — that is, what exactly do we mean when we say a situation is "twice as glaring," "twice as noisy," "twice as bright"? All that can be accepted at the moment is that such concepts are meaningful to many people, that they can be judged consistently. It will be recalled that a great

deal of useful scientific work was done with such judgments of sensation magnitudes (*e.g.*, the scale of stellar magnitudes) in the days before suitable measuring equipment was available.

Acknowledgments

This paper records work done at the Building Research Station, England, one of us (Bradley) working with a grant from the Illuminating Engineering Research Institute. We acknowledge the permission of the Director of the Building Research Station and the Illuminating Engineering Research Institute to publish the paper.

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APPENDIX

Straight line plots were found appropriate and useful in the subsequent analysis and do not appear inconsistent in consideration of the data and their use. The data are not presented in the sense of complete and exact quantitative relationships between variables, and should not be, by reason of the small amount of data. Hence, from Fig. 1 only an average slope for the median plot has been determined for use in equations 1 and 2. Little variation in slope is obtained, however, with the best fit straight line for the total data in Fig. 1, rather than the forcing of a plot through the glare discomfort reference conditions as was done. This slope, as well, happens to coincide with one which could similarly be determined for mean points.

From Fig. 1:

$$\log G_D = x \log B_b + \log K_3 \quad \text{where } x = -\tan 38^\circ = -0.78 \qquad \left| \begin{array}{c} B_S = K_1 \\ \omega = K_2 \\ X/20 \leq G_D \leq 20X \end{array} \right. \tag{1}$$

and therefore

$$G_D = K_3 B_b^{-0.78} \qquad \left| \begin{array}{c} B_S = K_1 \\ \omega = K_2 \\ X/20 \leq G_D \leq 20X \end{array} \right. \tag{2}$$

In undertaking this experiment, the results of Fig. 1 were analyzed before those of Fig. 2 were compiled and examined. This was done so that a theoretical value (denoted y') of the empirical exponent y in the equation $G_D = K_8 B_S^{y}$, for constant B_b and ω would be in hand before analysis of Fig. 2 data, and derived from the data obtained by varying surround brightness. This value could be checked with that directly obtained from the data of varying source brightness. To find y, the Building Research Station glare formula, $G_c = \dfrac{K_4 B_S^{1.6} \omega^{0.8}}{B_b}$, was used. Since from (2),

$$G_D = K_3 B_b^{-0.78} \qquad \left| \begin{array}{c} B_S = K_1 \\ \omega = K_2 \\ X/20 \leq G_D \leq 20X \end{array} \right.$$

and combining these two equations for $B_S = K_1$ and $\omega = K_2$:

$$G_D = K_5 G_C^{0.78} \qquad \left| \begin{array}{c} B_S = K_1 \\ \omega = K_2 \\ X/20 \leq G_D \leq 20X \end{array} \right. \tag{3}$$

Now assuming (3) is valid for constant B_b and ω, using the BRS glare formula again, it can be shown:

$$G_D = K_6 B_S^{1.25} \qquad \left| \begin{array}{c} B_b = K_7 \\ \omega = K_2 \\ X/20 \leq G_D \leq 20X \end{array} \right. \tag{4}$$

From the data of Fig. 1, and making certain assumptions, y' therefore equals 1.25.

From Fig. 2 the exponent y is found as follows from the best fit line, through the reference condition, for the median points. (The best fit line for mean points very nearly coincides):

$$\log G_D = y \log B_S + \log K_8 \quad \text{where } y = \tan 50.8^\circ = 1.23 \qquad \left| \begin{array}{c} B_b = K_7 \\ \omega = K_2 \\ X/20 \leq G_D \leq 20X \end{array} \right. \tag{5}$$

and therefore

$$G_D = K_8 B_S^{1.23} \qquad \left| \begin{array}{c} B_b = K_7 \\ \omega = K_2 \\ X/20 \leq G_D \leq 20X \end{array} \right. \tag{6}$$

Data were taken at glare discomfort conditions of $20X$ and $X/20$ with first the background brightness as the visible variable, and then the source brightness. These were not employed in the mathematical calculations since several of the observers were limited in the desired brightness for these conditions by the experimental apparatus. Hence, the data are not presented herein. However, they do show point to point median plots, if drawn on the data in Figs. 1 and 2, to be less curvilinear than may appear through examination of the median points in the range of $10X$ to $X/10$.

The exponent relating G_D and B_S, derived first by data of varying surround brightness, is seen to be quite close to that found secondly by data of varying source brightness. This correlation gives some confidence that the assumptions made were valid, and that the exponents of the Building Research Station glare formula are valid for the conditions of the experiment, whether the judgments are made by a multiple criterion method or by a sensation magnitude method.

It is now possible to relate these sensation magnitude judgments with the steps on the multiple criterion scale. As determined by Hopkinson and Petherbridge, for six experienced observers, the glare constants corresponding to the two criteria of discomfort, just intolerable ($\bar{A}$) and just imperceptible ($\bar{D}$), are, respectively, 600 and 8, with the

four criteria A, B, C and D being equally spaced on a logarithmic glare constant scale. Therefore*:

$$\frac{\bar{A}G_C}{\bar{D}G_C} = \frac{600}{8} = 75 \quad \text{and}$$

$$\log\left[\frac{\bar{A}G_C}{\bar{D}G_C}\right] = \log 75 = 1.88 \quad \text{and} \tag{7}$$

$$\log\left[\frac{\bar{A}G_C}{\bar{B}G_C}\right] = \log\left[\frac{\bar{B}G_C}{\bar{C}G_C}\right] = \log\left[\frac{\bar{C}G_C}{\bar{D}G_C}\right] = \frac{1.88}{3} = 0.626 \tag{8}$$

But from (3) (or as could be shown by taking (6) and working back through the BRS glare constant formula):

$$\log\left[\frac{\bar{A}G_D}{\bar{B}G_D}\right] = \log\left[\frac{BG_D}{CG_D}\right] = \log\left[\frac{CG_D}{DG_D}\right]$$

$$= 0.78 \log\left[\frac{AG_C}{BG_C}\right] = 0.78 \log\left[\frac{BG_C}{CG_C}\right] = 0.78 \log\left[\frac{\bar{C}G_C}{\bar{D}G_C}\right] \tag{9}$$

Combining (8) and (9):

$$\log\left[\frac{\bar{A}G_D}{\bar{B}G_D}\right] = \log\left[\frac{\bar{B}G_D}{\bar{C}G_D}\right] = \log\left[\frac{\bar{C}G_D}{\bar{D}G_D}\right]$$

$$= 0.78 + 0.626 = 0.488 \tag{10}$$

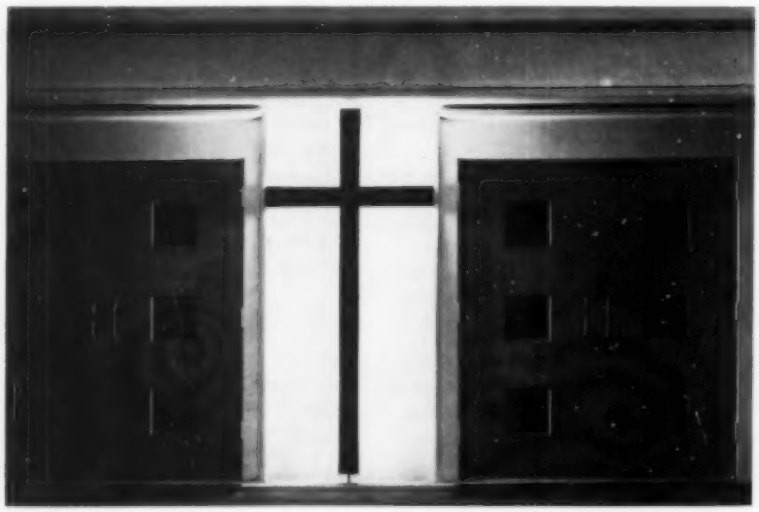
$$\text{or} \quad \left[\frac{\bar{A}G_D}{\bar{B}G_D}\right] = \left[\frac{\bar{B}G_D}{\bar{C}G_D}\right] = \left[\frac{\bar{C}G_D}{DG_D}\right] = \text{antilog } 0.488 = 3. \tag{11}$$

On the average, therefore, if the data be valid, a step of one criterion (or an increase in glare constant G_C by a factor of approximately 4 ($G_C \geq 8$) for the experimental conditions) appears to be equal to about three times as uncomfortable a glare situation. The relationship is an average one and no inference is made regarding range or variance of the population in consideration of the sampling used.

*In the following equations it should be noted that $\bar{A}$, $\bar{B}$, $\bar{C}$, $\bar{D}$ are not separate mathematical operators but are used as shown in this example:
$\bar{A}G_D$ = glare constant at criterion A.
$\bar{A}G_C$ = glare constant at criterion A.

Silhouetting a Cross

Mounted between two doors entering the First Baptist Church of South Gate, Calif., a 7½-foot high cross is silhouetted against the wall behind it. Other dimensions are: cross-arm, 3 feet 7 inches; distance from wall, 6 inches; mounting height above floor, 5½ feet. The cross is made from 5-inch-square sections of wood. Silhouetting is by one 40-watt, one 30-watt and two 15-watt fluorescent lamps, recessed in the channel in the back of the cross. Photo and data courtesy of Joseph A. Northrop, Southern California Edison Co., Long Beach.



INSTALLATION AT HOLOPHANE COMPANY, NEW YORK, N. Y.

Lighting a Private Office

LIGHTING OBJECTIVE: To provide high level, comfortable illumination for an executive office.

GENERAL INFORMATION: This office is 16 feet long and 15 feet wide with a height of 9 feet to the plastic lens ceiling. The plenum depth is 14 inches. Colors and reflectances of the major room surfaces are as follows:

plenum	white	70% RF	desk		
ceiling	white	75% RF	top	cream	42% RF
walls			sides	gray	20% RF
upper	white	75% RF			
lower	warm buff	55% RF	blinds	cream	38% RF
chairs			draperies	green	11% RF
	salmon	20% RF	floor	taupe	20% RF
	straw	25% RF			

(over)

A.I.A. File No. 31

INSTALLATION: This luminous ceiling is divided into two panels, each 6 feet by 12 feet. Continuous rows of 40-watt rapid-start cool white fluorescent lamps are spaced on 6-inch centers, 8 inches above Holophane No. 6024 Prismalume plastic lenses. The lamps can be switched to give three illumination levels: 85, 170 and 255 footcandles. Average brightnesses of the luminous ceiling and of major room surfaces for the 170-footcandle level after 900 burning hours measured:

luminous ceiling		ceiling	
55-degree vertical angle, across lamp axis	380 fL	center	29 fL
		side	45 fL
55-degree vertical angle, along lamp axis	330 fL	walls	
		upper	45 fL
65-degree vertical angle, across lamp axis	195 fL	lower	64 fL
		floor	23 fL
65-degree vertical angle, along lamp axis	190 fL	desk	
		top	72 fL
75-degree vertical angle, across lamp axis	120 fL	side	6 fL
		blinds	63 fL
75-degree vertical angle, along lamp axis	130 fL	drapes	18 fL
		chair	18 fL

Lighting designed by Robert V. Smith, Holophane Co., Inc., New York, N. Y.

Lighting data submitted by Emanuel Berger, Holophane Co., Inc., New York, N. Y., as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

Recommended Levels for Selling the Goods

"No other field of illumination presents as broad an opportunity for engineering and design skill as the lighting of present-day merchandising areas. These range in size from the small one-man shop with simple merchandise to the large department store with acres of space, great diversity of goods and thousands of employees. Moreover, they vary widely in clientele and styling, as well as in competition." *IES Lighting Handbook, Third Edition.*

This quotation sums up, in general, the wide scope for individual treatment in general lighting for stores, display and decorative lighting, or any other use of light to achieve a common end—whatever the nature of the store—that of inducing the customer to buy.

(Photo and data credits appear on page 508, keyed to the letters at the end of captions.)

Large area of luminous ceiling along the front of this drugstore (above) provides a welcoming element. Elsewhere (below) four-foot-square recessed fluorescent units supply 80 footcandles in the sales area, with adjustable incandescent spots recessed in the ceiling, producing an additional 50 footcandles of accent lighting. Valances are used on wall cases. (A)

Average general illumination of 115 footcandles is provided by luminous ceiling panel system with 96-inch T12 cool white lamps. There is double this amount on key displays from recessed spots. (B)

Panels of two layers of thin vinyl sheeting with an air space between have sound-absorbing qualities in addition to improved light diffusion. Above each panel are six rows of continuous strip of two-lamp 96-inch slimline lamps on 12-inch centers. Luminous panels provide a maintained level of 125 to 130 footcandles. Around the perimeter of the ceiling are 49 recessed incandescent spots for highlighting the appliances on display. (C)

Reflections from glass of these show windows are minimized by the use of a luminous panel for the back wall. The panel has 96-inch T12 lamps mounted on 12-inch centers behind the diffusing plastic. General lighting of 200 footcandles is provided by a two-lamp troffer with 96-inch T12 lamps and 300-watt incandescents in mirrored glass reflectors. (D)

Equipment used for general lighting in this women's apparel shop consists of twenty plastic-shielded 2- by 8-foot fixtures, each using four 96-inch T12 warm white deluxe lamps. Wall case lighting is by 76 feet of 48-inch T12 lamps in single strip. Other equipment, for highlighting, consists of 19 three-lamp wall case incandescent bracket lights, 14 eyeball spots recessed in show window floors and 24 hood type fixtures equipped with 150-watt R40 spot lamps. (E)

Stores	Currently Recommended Illumination* Footcandles
Show windows	
Daytime lighting	
General	200
Feature	1000
Nighttime lighting	
Main business districts — highly competitive	
General	200
Feature	1000
Secondary business districts or small towns	
General	100
Feature	500
Open-front stores (see Display lighting under Store interiors)	
Store interiors	
Circulation areas	30
Merchandising areas	
Service	100
Self-service	200
Showcases and wall cases	
Service	200
Self-service	500
Feature displays	
Service	500
Self-service	1000

(1) Above values are illumination on the merchandise on display or being appraised. The plane in which lighting is important may vary from horizontal to vertical.
(2) Specific appraisal areas involving difficult seeing may be lighted to substantially higher levels.
(3) Color rendition of fluorescent lamps is important. Incandescent and fluorescent usually are combined for best appearance of merchandise.
(4) Illumination may often be made non-uniform to tie in with merchandising layout.
*Minimum on the task at all times.

Levels of around 2500 footcandles are achieved in the L-shaped show window at the left, using 24 reflector units, twelve with 300-watt PS35 lamps and 12 with 200-watt A25 lamps. Window dimensions are: 4 feet 9 inches across the front, 12 feet 9 inches long, 2 feet 3 inches deep and 4 feet high. Heat is exhausted into a 5-foot plenum by a centrifugal fan. (F)

General maintained illumination level in this department store is 125 footcandles, provided by 8-foot-square recessed troffers with low-brightness lenses. Lamps used are 96-inch cool white deluxe slimlines. Special luminous fixture over coat rack and valances on walls highlight displayed merchandise. (G)

Extra-high-output lamps, with plastic diffusers, are recessed in the steel roof decking of the ceiling (as is the sprinkler system, too) in continuous rows on 6-foot centers for 100 footcandles general illumination. End displays and produce are highlighted to 200 footcandles by PAR56 units. (H)

Photo Credits

A (two photos)—Line Material Industries, South Milwaukee, Wis.

B, D, H, K, L, N, and O—General Electric Co., Cleveland, Ohio.

C—Baltimore Gas & Electric Co., Baltimore, Md.

E, I, J, M—San Diego Gas & Electric Co., San Diego, Calif.

F—Consumers Power Co., Grand Rapids, Mich.

G—Texas Power & Light Co., Dallas, Texas.

Twenty-five 8-foot and four 4-foot 4-lamp fixtures with 45-degree louvering and plastic side panels, in store at left, use standard cool white lamps for 120 footcandles. Incandescent bullet units highlight displays. (I)

Ceiling-mounted between beams of this 2537-square-foot store, fixtures each using four 8-foot T12 warm white deluxe lamps supply general lighting of 70 footcandles. Luminous ceiling area in the dress department attracts customers to the rear of the store. (J)

Suspended louvered fixtures with plastic sides and extra-high-output lamps are mounted in continuous rows for a maintained level of over 160 footcandles. Incandescent units are used over the meat and produce departments and spotlights over displays. (K)

A combination of fluorescent and incandescent lighting results in 200 footcandles in this supermarket. Troffers each have eight 96-inch T12 warm white lamps, and the incandescent lighting is supplied by recessed 150-watt R40 floods. (L)

Surface-mounted units, with vinyl plastic diffusers, are mounted in continuous rows along the sides of this shoe store—over the "trying-on" area and the shelves of stock. Over the center aisle are sets of two of the 8-foot fixtures. Average maintained illumination is 120 footcandles. Lamps are standard cool white slimline. (M)

Luminous ceiling, with 96-inch T12 cool white deluxe lamps, provides 100 footcandles general illumination. Luminous showcase on back wall, for displaying glassware, has panel brightness of 150 footlamberts. (N)

General lighting of 100 footcandles is supplied by 96-inch T12 cool white deluxe lamps on 24-inch centers in a plastic lens system. Display lighting uses 150-watt R40's for accent. (O)

Some Aspects of

Luminance and Luminous Emittance

By W. A. HEDRICH

SELDOM is the mere definition of an entity in the physical sciences or its defining equation sufficient to enable one to acquire a profound understanding of its significance as related to other entities in the system. This is also true in connection with luminance and luminous emittance. A visual environment is conditioned by cause and effect. Light source characteristics, the Inverse Square Law, properties of light-controlling media, and interreflection theory all play an important role in establishing a visual environment — desirable or undesirable. Both luminance and luminous emittance are related to other entities in the photometric system as will be shown presently.

Apart from the results produced by phenomena such as polarization, diffraction, etc., the luminous emittance at one point of a surface may differ from that at another point on the same surface because of variation in reflectance of the surface, variation in transmittance of the material or, as in the case of primary emission, the $\kappa \int_{\lambda_1}^{\lambda_2} \nu_\lambda J_\lambda d\lambda$ may differ for different elements of the same surface or for distinctly different non-contiguous surface. When either reflection or transmission of light or both are involved, the spectroradiometric function of the light source as well as the spectral reflectance and/or transmittance of the medium are responsible for differences in power densities and consequently differences in luminous emittance. There may also be supplementary components of luminous emittance in the event transmitting and reflecting media are involved when the atomic structure of the media is such as to promote self-excitation within the range of the visible part of the spectrum due to transmitted or reflected light. In all cases the luminous emittance, which expresses the power density (power per unit area) evaluated in terms of the photometric standard observer for photopic vision (sometimes referred to as the luminosity function), is determined by the nature and mode of operation of the source. Luminous emittance is then primarily attributable to the predominating influences of operating temperature and state of excitation.

The solid angular distribution of light flux from an elementary area is not the result of specifying the luminous emittance. Intensity distributions from an elementary area may be widely different for a given M, depending largely upon the structure of the surface or that of the transmitting medium. Likewise, in the case of a light source or luminaire, intensity distribution varies with their design characteristics. Even the intensity distribution of an element of a surface, quite apart from its luminous emittance, cannot be arbitrary, since the flux per unit solid angle cannot be multivalued. The same is true for a complete source for which the operational definition of intensity

$$I_\alpha = \lim_{d \to \infty} \frac{E_M d^2}{\cos\beta} = \lim_{d \to \infty} E_N d^2$$

subscribes to the single-valued aspect of intensity in a specified direction. See Fig. 1.

As far as luminance (brightness) is concerned, there are arguments both for and against its use as a photometric entity. Recession in the use of this concept is followed by revival, especially in unrestrained and practical reference. Present-day use of the expression "brightness" in professional circles is often aimed to provide a quasi-quantitative specification of subjective appraisal of comfort and discomfort in a visual environment. Nevertheless, not only the reluctance to abandon the use of an

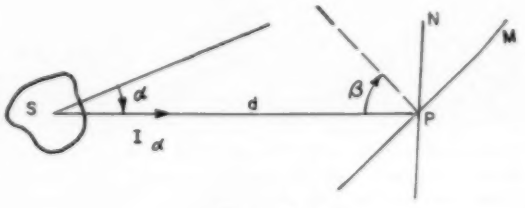


Figure 1.

AUTHOR: Dept. of Electrical Engineering, Univ. of Michigan, Ann Arbor, Mich.

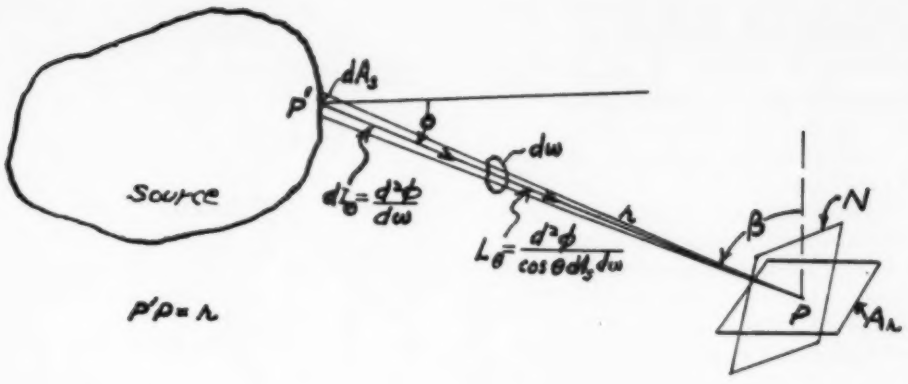


Figure 2.

expression like luminance (brightness), but on the contrary a predominant increase in its use by practicing engineers in the field of illumination warrant a brief review of the objective aspects of luminance punctuated by the necessary "Stop" and "Go" signals to emphasize its limitations.

The mathematical equivalent of the definition of luminance $L_\theta = \dfrac{dI_\theta}{\cos\theta dA_s}$ (the subscript s refers to the source) is based on the quotient of luminous intensity in a given direction of an infinitesimal element of a surface containing a point under consideration by the orthogonally projected area of the element on a plane normal to the given direction. Obviously L relates intensity to area, and intensity is defined as $I = \dfrac{d\phi}{d\omega}$, the flux per unit solid angle. Evidently intensity as well as luminance are properties of a source element. These terms may also be referred to a complete source when the Inverse Square Law can be applied to yield reasonably accurate results. A definition of intensity $I = \dfrac{d\phi}{d\omega}$ quite logically emerged from the consideration that visually-evaluated radiant energy flow in general persisted in various directions from a source, and quite so even when the latter must be treated as a finite body. This divergence of energy flow in various directions from the source could easily and logically lead to the adoption of the solid-angle concept. The latter, however, involving projected area, is not restricted to the field of illumination. Magnetostatic field theory, for example, expresses potential and field intensity in space due to an array of dipoles through the solid-angle concope. It follows that

$$dI_\theta = \frac{d^2\phi}{d\omega} \quad \text{and} \quad L_\theta = \frac{d^2\phi}{\cos\theta dA_s d\omega} \qquad \text{(See Fig. 2)}$$

The Inverse Square Law inherently relates cause and effect. Thus while I and L are properties of the source, it is sometimes not only more convenient but necessary from the standpoint of measurement to relate luminance to effect — the illumination established at some point P. Since $E_P = \dfrac{I_\theta}{r^2}\cos\beta$ on A_r,

$$L_\theta = \frac{dI_\theta}{\cos\theta dA_s} = \frac{r^2}{\cos\theta\cos\beta}\frac{dE_P}{dA_s} = \frac{1}{\cos\beta}\frac{dE_P}{\dfrac{dA_s\cos\theta}{r^2}}$$

$$= \frac{dE_P}{\cos\beta d\omega} = \frac{dE_{Pn}}{d\omega} \qquad (1)$$

where dE_{Pn} is the differential illumination on the surface N at P normal to the direction r. Since the actual illumination at P on N due to a finite portion of the source is $E_{Pn} = \int dE_{Pn}$, any part of the complete source contributing toward the power density at P can be masked, and the remainder contributing toward that at P will establish an E_{Pn} which can be measured, the solid angle subtended at P by the unmasked portion computed, and at least an average of L for the exposed part of the source determined. This procedure has merit. Indiscriminate application may result in serious error. If the luminance of the exposed portion of the source varies greatly from point to point, the result obtained will not represent L at all points. The error can be minimized by restricting measurements to smaller exposed areas.

From the definition of luminance it is obvious that the projected area of the element may vanish, in which case the solid angle tends toward zero. While perhaps momentarily disconcerting, a practical appraisal of the situation reveals that the intensity must approach a finite value for a real source from which the power density is essentially unidirectional.

What then happens to the luminance? There are

other questions pertaining to the luminous emittance which require some consideration before satisfactory conclusions may be reached. A typical illustration would be the case of a hemisphere luminous on its concave surface with constant luminance L. The flux emitted by this hemispherical surface is $\phi = MA = \pi L\, 2\pi R^2 = 2\pi^2 R^2 L$. Conventional references establish an illumination under these conditions anywhere on the diametral plane (except at points along the circumference of the base of the hemisphere) of $E = \pi L$. Thus the flux intercepted by the base is $\phi = EA$ or $\phi = \pi L \pi R^2 = \pi^2 R^2 L$, only half of that emitted by the hemisphere. Any flux components due to interreflection are here neglected. The discontinuity in E at the boundary of the base has no effect as far as the flux is concerned since the boundary contributes no area.

The answer to the question at the beginning of the preceding paragraph may be arrived at as follows. Although in general $L = f(\alpha, x, y, z)$, consider for the moment that $L = (\alpha)$ only for the case that $dI_\alpha = dI_{max} \cos^m \alpha$, an axially symmetric intensity distribution. For $m = 1$ this represents the idealized cosine emission. Then for m a positive integer

$$\lim_{m \to \infty} \cos^m \alpha = 0 \qquad \text{for } 0 < \alpha \leq {}^{\pi}/_{2}$$

and

$$\lim_{m \to \infty} \cos^m \alpha = 1 \qquad \text{for } \alpha = 0.$$

The intensity is everywhere constant and normal to the element and equal to dI_{max}. Then

$$L = \frac{dI_\theta}{\cos\theta\, dA_s} = \frac{dI_{max}}{dA_s} \qquad \text{(exists only for } \alpha = 0) \qquad (2)$$

A finite surface exhibiting this property could theoretically not be seen unless viewed normal to the surface since both the intensity and luminance vanish for all angles from 0 to $\pm{}^{\pi}/_{2}$ except for $\alpha = 0$. It is the theoretical equivalent of a source emitting unidirectional (parallel rays). The surface is not uniformly diffuse. Now referring to Fig. 3 and assuming the element dA_s to be uniformly diffuse,

$$dI_\alpha = dI_{max} \cos\alpha, \qquad L = \frac{dI_{max}}{dA_s}$$

$$dE = \frac{dI_\alpha}{R^2} = \frac{L\, dA_s \cos\alpha}{R^2} \qquad (3)$$

$$dA_r = 2\pi R^2 \sin\alpha\, d\alpha$$

$$d\phi' = dE\, dA_r = 2\pi L\, dA_s \sin\alpha \cos\alpha\, d\alpha$$

Integration between limits 0 and α yields

$$d\phi' = \pi L\, dA_s \sin^2\alpha = \pi L\, dA_s (1 - \cos^2\alpha)$$

$$\frac{d\phi'}{dA_s} = \pi L (1 - \cos^2\alpha) \qquad (4)$$

The left member of Eq. 4 *appears to be* the luminous emittance of the element dA_s and as such would be a function of α. However, the restriction of α to angles less than ${}^{\pi}/_{2}$ could mark the condition of luminance control referred to in a previous article, and if the definition of luminous emittance involves the ratio of the total flux emitted by the surface element to the area of that element, then M is still $\dfrac{d\phi'}{dA_s}$ for and only for $\alpha = {}^{\pi}/_{2}$. This supports the non-directional aspect of luminous emittance.

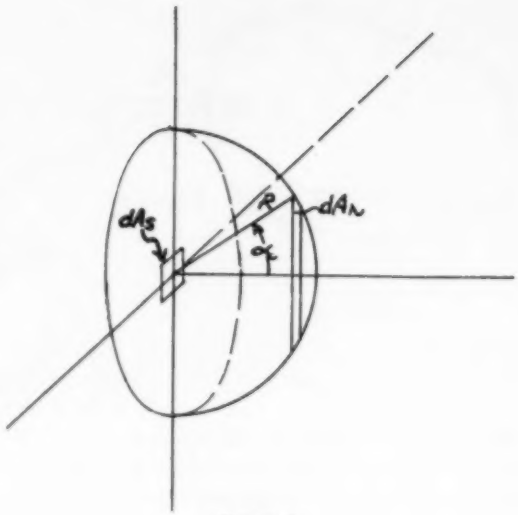


Figure 3.

Proceeding to the general case

$$dI_\alpha = dI_{max} \cos^m \alpha, \qquad (5)$$

$$L = \frac{dI_\alpha}{dA_s \cos\alpha} = \frac{dI_{max} \cos^{m-1}\alpha}{dA_s} \qquad (6)$$

for which

$$L = L_{max} \cos^{m-1}\alpha \quad \text{where} \quad L_{max} = \frac{dI_{max}}{dA_s} \qquad (7)$$

$$dE = \frac{dI_\alpha}{R^2} = \frac{L\, dA_s \cos^m\alpha}{R^2 \cos^{m-1}\alpha} = \frac{L_{max}\, dA_s}{R^2} \cos^m\alpha$$

$$d\phi = dE\, dA = 2\pi L_{max}\, dA_s \sin\alpha \cos^m\alpha\, d\alpha. \qquad (8)$$

Note that for $m = 2$ it is the luminance that follows the idealized cosine emission pattern. For the general case, however, integration from zero to α yields

$$d\phi' = 2\pi L_{max}\, dA_s \frac{(1 - \cos^{m+1}\alpha)}{m+1} \qquad (9)$$

$$\frac{d\phi'}{dA_s} = 2\pi L_{max} \frac{(1 - \cos^{m+1}\alpha)}{m+1} \qquad (10)$$

For the limiting condition $m \to \infty$,

$$\frac{d\phi'}{dA_s} = 2\pi L_{max} \cdot \lim_{m \to \infty} \frac{(1 - \cos^{m+1}\alpha)}{m+1} = 0 \qquad 0 \leq \alpha \leq {}^{\pi}/_{2}$$

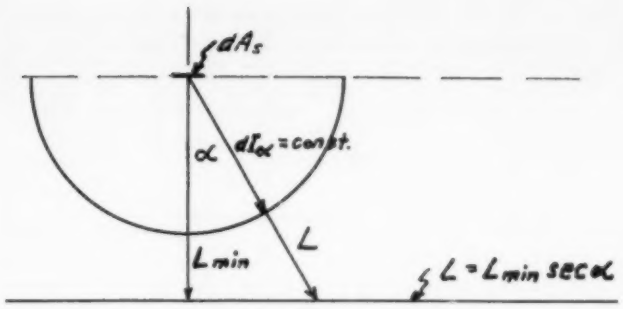


Figure 4. $m = 0$.

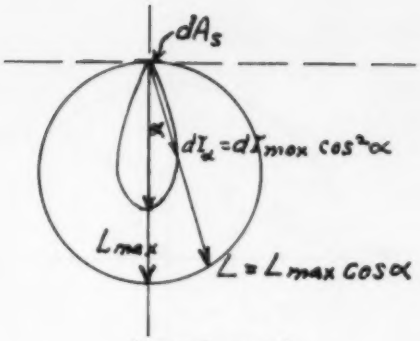


Figure 6. $m = 2$.

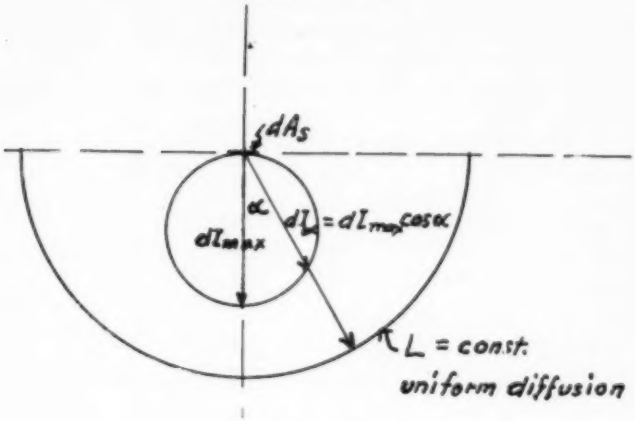


Figure 5. $m = 1$.

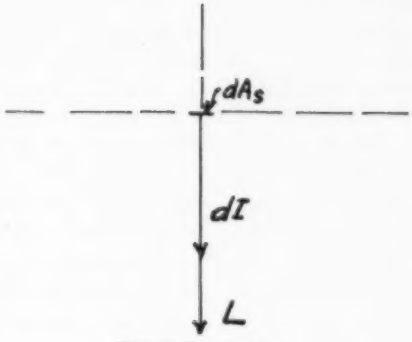


Figure 7. $m \to \infty$.

Equation (10) will give the luminous emittance M for all luminance patterns of the type $L = L_{\max} \cos^{m-1} \alpha$ corresponding to $dI_\alpha = dI_{\max} \cos^m \alpha$ provided $\alpha = \pi/2$. Thus $M = \dfrac{2\pi L_{\max}}{m+1}$ reveals diminishing luminous emittance for a specified $L_{\max}$ as m increases. Also from Eq. (5) it may be seen that for $m = 0$ the locus of intensity is a hemisphere with center at the source, the luminance from Eq. (7) is $L = L_{\min} \sec \alpha$, the locus of which is a plane parallel to and distant $L_{\min}$ from the source, and the luminous emittance becomes $M = 2\pi L_{\min}$.

The relation between M and L is always obtained by extending the integration from 0 to $\pi/2$ for a surface element exhibiting axially symmetric intensity distribution regardless of whether the surface is uniformly diffuse or not. A few distributions are shown in Figs. 4, 5, 6 and 7. The investigation could be extended to cover all real values of m. For asymmetric intensity distributions the integration should be extended from $-\pi/2$ to $+\pi/2$. The more general case of $L = f(\alpha, x, y, z)$ is beyond the scope of this discussion.

Luminous emittance, as defined, is not the controversial issue in this discussion. It is clearly and uniquely defined and serves its purpose in illumination theory. Since it serves to determine luminous flux from a source, the issue is clearly one of its relation to other entities in the photometric system. The flux intercepted by a surface due to a luminous source involves illumination and area. The flux concept, whether employed in illumination or electromagnetic theory is the same, namely, $d\phi = \overline{D} \cdot \overline{dA}$, the scalar product of flux density and area. Vector procedures have been introduced into illumination theory by authors like Moon,[1] Gershun, Gurevic, Helwig[2] and others. The latter, for example, introduces a vector point function $\overline{D} = \dfrac{I}{r} \bar{r}_1$ as a property of space due to a point source of light, in which the absolute value of $\overline{D}$ is taken as the normal (maximum) illumination on a surface element containing the point under consideration, and the magnitude of the projection of $\overline{D}$ along any direction prescribes the scalar illumination on the area normal to this direction. For the purpose of this discussion it is sufficient to observe that luminous flux is a scalar and is obtained in differential form as $d\phi_r = dE_n \, dA_r$. (11)
The subscript r refers to the receiving area.

In the following, attention is focused on flux per

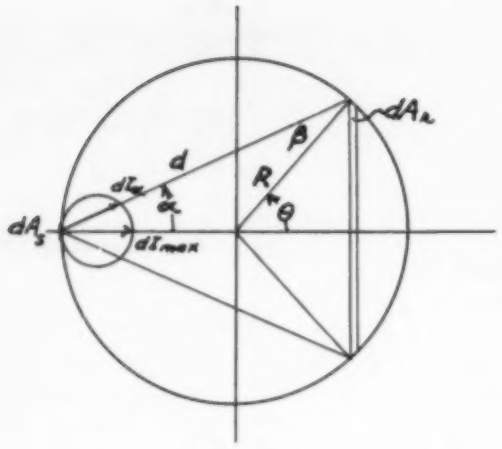


Figure 8.

unit area of emitter rather than on luminous flux itself. Consider a luminous sphere emitting from within according to the cosine law. See Fig. 8. Interreflections are not a part of this consideration. Any element dA_s will illuminate all surface elements of the sphere. If $d\phi$ is the flux from dA_s intercepted by the receiving element dA_r, then

$$dE_s = \frac{L\,dA_s \cos\alpha \cos\beta}{d^2}$$

$$dA_r = 2\pi R^2 \sin\theta\, d\theta$$

$$d^2 = 2R^2(1+\cos\theta)$$

$$\alpha = \beta = \frac{\theta}{2}, \qquad d\phi = \frac{\pi L\,dA_s}{2}\sin\theta\, d\theta$$

Integrating with respect to θ,

$$d\phi' = \frac{\pi L\,dA_s}{2}(1-\cos) = \pi L\,dA_s \sin^2\alpha \qquad (12)$$

Only for $\theta = \pi$ or $\alpha = {}^{\pi}/_{2}$ is this result the luminous emittance of dA_s. Yet $\dfrac{d\phi'}{dA_s} = \pi L \sin^2\alpha$ prescribes the ability of dA_s to establish flux on any zonal area for α from 0 to ${}^{\pi}/_{2}$. The luminous emittance of the sphere is $M = \left|\dfrac{d\phi'}{dA_s}\right|_{\alpha = {}^{\pi}/_{2}} = \pi L$. Equation (12) simply expresses the flux on any zone as a function of θ or α.

In order to prescribe the relative effectiveness of a uniformly diffuse element in establishing luminous flux on a specified surface, consider again the case of a hemisphere luminous on its concave surface with L = const. If, for example, the flux incident on the base FG of the hemisphere is desired for an *arbitrary position* of the emitting element dA_s on the hemisphere, then referring to Fig. 9

$$d\phi = dE_s\, dA_r$$

$$dA_r = \rho\, d\rho\, d\lambda \qquad (\lambda \text{ in diametral plane } FG)$$

$$dE_s = \frac{L\,dA_s \cos\alpha \cos\beta}{d^2}$$

$$d\phi = \frac{L\,dA_s \cos\alpha \cos\beta}{d^2}\rho\, d\rho\, d\lambda \qquad (13)$$

The location of dA_s on the hemisphere is determined by R and θ. Due to circular symmetry the flux from dA_s on the hemispherical base is the same for any azimuthal angle ψ for a given θ. Trigonometric relations determine:

$$d^2 = \rho^2 + R^2 - 2R\rho\cos\theta,$$

$$\cos\beta = -\frac{R\sin\theta}{\sqrt{\rho^2+R^2-2R\rho\cos\theta}},$$

$$\cos\alpha = \frac{R-\rho\cos\theta}{\sqrt{\rho^2+R^2-2R\rho\cos\theta}}.$$

Thus, $$d\phi = -L\,dA_s \frac{R\sin\theta(R-\rho\cos\theta)}{(\rho^2-2R\rho\cos\theta+R^2)^2}. \qquad (14)$$

Integration with respect to λ in Eq. (13) yields 2π, so that

$$d\phi' = -2\pi L\,dA_s\left[\int_{\rho=0}^{\rho=R}\frac{R^2\sin\theta\rho\, d\rho}{(\rho^2-2R\rho\cos\theta+R^2)^2} - \int_{\rho=0}^{\rho=R}\frac{R\sin\theta\cos\theta\rho^2 d\rho}{(\rho^2-2R\rho\cos\theta+R^2)^2}\right] \qquad (15)$$

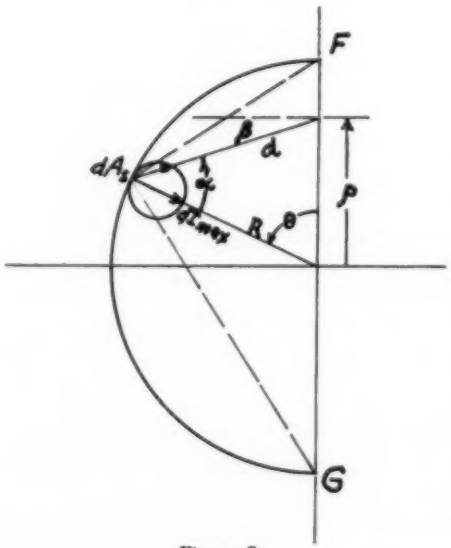


Figure 9.

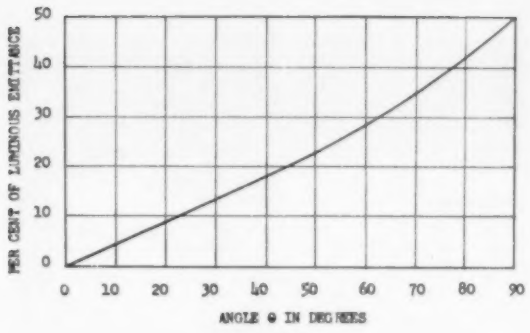


Figure 10.

Integrating with respect to ρ, substituting and simplifying,

$$d\phi' = \frac{\pi L dA_s}{2} \frac{(1-\cos\theta)}{\sin\theta} \tag{16}$$

$d\phi'$ is now the differential flux on the base of the hemisphere for any position of the uniformly diffuse emitting element dA_s. For $\theta = 0$ $d\phi'$ becomes zero by observing that

$$Lim_{\theta \to 0} \frac{f(\theta)}{F(\theta)} = Lim_{\theta \to 0} \frac{f'(\theta)}{F'(\theta)} = \frac{f'(0)}{F'(0)} = \frac{0}{1} = 0.$$

All other values of $d\phi'$ are obtained by direct evaluation for θ. Thus

$$\frac{d\phi'}{dA_s} = \frac{\pi L}{2}\left(\frac{1-\cos\theta}{\sin\theta}\right) \tag{17}$$

gives the percentage of luminous emittance which is effective in establishing flux on the base of the hemisphere as shown by the curve in Fig. 10. The luminous emittance of the element is everywhere the same and is $M = \pi L$ since $L = \text{const}$. However, for dA_s in the 70-degree position, only about 35 per cent of the luminous emittance is effective in establishing flux on the base FG. Fig. 10 shows per cent of luminous emittance $M = \pi L$ for uniformly diffuse hemisphere (emitting from its concave surface) which is intercepted by the base of the hemisphere as function of position of the emitting element dA_s.

Usually one is not interested in the differential flux established on a specified surface due to a single luminous element, but desires the total flux due to a finite luminous surface. For the problem under consideration the total flux ϕ' on the base due to the entire hemisphere is

$$\int d\phi' = \pi^2 R^2 L \int_0^{\pi/2} \cos\theta \frac{(1-\cos\theta)}{\sin\theta} d\theta = \pi^2 R^2 L = M\pi R^2$$

Similarly the total flux ϕ'' not incident on the base of the hemisphere, but intercepted by the hemisphere itself is

$$\int d\phi'' = 2\pi^2 R^2 L \int_0^{\pi/2} \left[1 - \tfrac{1}{2}\left(\frac{1-\cos\theta}{\sin\theta}\right)\right] \cos\theta d\theta$$

$$= \pi^2 R^2 L = M\pi R^2$$

and the total flux ϕ_s emitted by the hemisphere is

$$\int d\phi_s = 2\pi^2 R^2 L \int_0^{\pi/2} \cos\theta d\theta = 2\pi^2 R^2 L = M \cdot 2\pi R^2$$

This constitutes not only a formal solution of the problem cited earlier in the discussion, but emphasizes the relative effectiveness of luminous emittance in establishing flux distributions on intercepting surfaces.

In connection with the above, if the emitter were a surface such that $dA_s = f(R,\theta,\psi)$ with R also variable, then the flux from any finite portion of the emitter on any specified intercepting surface involves a quadruple integral. This may be seen directly from the general expression $d^2\phi = L\cos\alpha\, d\omega\, dA_s$ wherein L, even though a function of position and angle, introduces no new variables for a general surface, but $d\omega$ and dA_s involve a total of four variables. The flux, however, may be evaluated as a double integral through the application of Stokes' Theorem which is omitted here since it involves a formal treatment of field theory in illumination.

Although Eq. (17) applies to a specific geometry under the condition of constant luminance, a general expression for $\frac{d\phi'}{dA_s}$ as function of geometry and luminance pattern could be written. There is, however, no need for introducing a new entity to define $\frac{d\phi'}{dA_s}$ for $\alpha < \pi/2$ since this would only serve to complicate the theory underlying the illumination field. Any variation in luminance pattern or in spatial conditions would introduce $\frac{d\phi'}{dA_s}$ as a different function of L and space.

In summary, the luminance pattern of a source as well as the geometry and orientation of an arbitrary receiving surface determine the effectiveness of a given luminous emittance in establishing a flux distribution on the receiving area. *This condition exists independent of luminance control* and is

based on the assumption that the divergence of the illumination field is everywhere zero in the space under consideration. Throughout the discussion the Reciprocity Theorem may be used as a guide in checking the derived relations. Luminous emittance, on the other hand, provides a measure of available total flux per unit area of the emitter from which to draw upon to provide a flux distribution on a specified area. In general it is not possible to utilize all the flux per unit area incorporated in the definition of M, except when the emitted flux is desired. However, even for the general case of a luminous surface, $\frac{d\phi'}{dA_s}$ for any solid angle less than 2π will prescribe the variation in percentage of M useful in establishing an increment of flux anywhere in space.

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1. Moon, P.: *The Scientific Basis of Illuminating Engineering*, First Edition, pp. 303-308, McGraw-Hill Book Co., Inc., New York, N. Y. (1936).
2. Helwig, H. J.: "Die Feldtheorie in der Lichttechnik (Einfuehrung)." *Lichttechnik*, Helios-Verlag, Berlin-Borsigwalde, Seite 16, 2. Jahrgang, Heft 1, Januar 1950.
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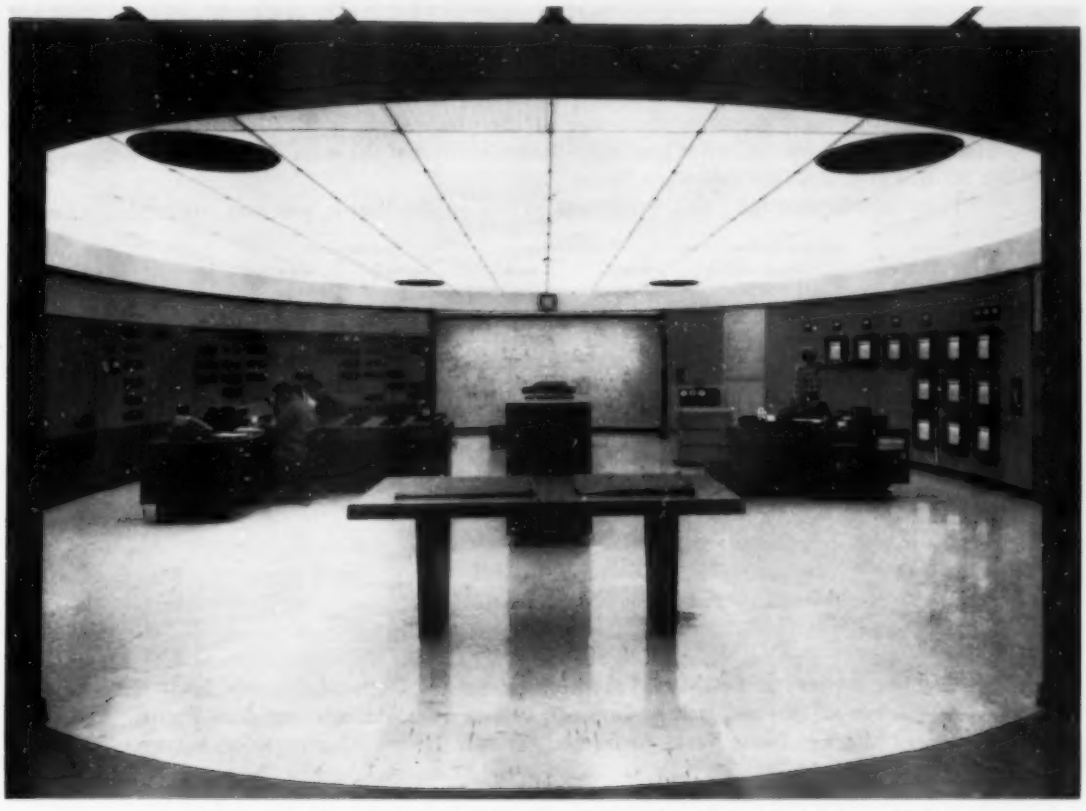
To Enhance a Floral Setting

Purchasing flowers is almost always a pleasant experience, and is made even more so when the florist's shop has a gracious atmosphere in which to make the purchase. Carren's Florist, in Dallas, Texas, achieves an open airy appearance with a glass front and a luminous panel ceiling which extends partially out over the entrance-way. Illumination level is an average 45 foot-candles from two rows of 2-lamp strip with a plastic diffuser in a wooden frame. Lamps used are standard cool white. Room dimensions are 14- by 28-feet with ceiling height of 8½ feet to the plastic; cavity depth is 28 inches. Walls are green and brown, as is the floor, both with 50 per cent RF. Photo and data courtesy of the Dallas Power and Light Co., Dallas, Texas.



INSTALLATION AT CITY PUBLIC SERVICE BOARD, SAN ANTONIO, TEXAS.

Lighting a Control and Load Dispatch Room

LIGHTING OBJECTIVE: To provide a high level of general room illumination and vertical illumination on the system map and the dispatch boards, with a minimum of reflected glare in the meter glass covers.

GENERAL INFORMATION: This room is circular in shape with a diameter of 36 feet. The plastic ceiling is 9 feet 6 inches above the floor. The plenum above the plastic is 12 inches deep. Meters and distribution circuits are located on both horizontal and vertical surfaces. Colors and reflectances of the major room surfaces are as follows:

ceiling			floor	light tan	47% RF
plenum	white	80% RF	dispatch boards	green	28% RF
plastic	white	53% RF	map	tan	12% RF
desks and equipment	brown	18% RF			

INSTALLATION: Sixty-eight catalog No. S-2-140RS and 17 catalog No. S-140RS Benjamin Electric Mfg. Co. fluorescent strip units, mounted in continuous rows on 18-inch centers, 12 inches

(over)

A.I.A. File No. 31/

above the Panel-Glo ceiling (three- by three-foot corrugated vinyl plastic), provide an average level of 125 footcandles at desk height. These units are equipped with 40-watt T-12 standard cool white lamps (153 lamps in all).

The system map, shown in the center of the photograph, is illuminated by one Benjamin catalog No. TGSK-396-16 troffer located 18 inches in front of the map. This unit is equipped with six 96-inch T-12 standard cool white lamps.

Illumination (vertical) and brightness values on the boards and map are as follows:

distance down from top in inches	footcandles		footlamberts	
	boards	map	boards	map
12	73	85	20	10
24	73	107	20	13
36	73	101	20	12
48	73	90	20	11
60	72	83	20	10
72	68	72	19	9
84	67	60	19	7
96 (floor)	60	58	17	7

Brightness values at other locations are:

Panel-Glo ceiling at 45°	115 fL
desk	23 fL
floor	54 fL

Lighting designed by Gerard M. Baker, Mechanical and Electrical Engineer, San Antonio, Texas and Jack A. Chrismer, Division Sales Manager, Benjamin Electric Mfg. Co., Dallas, Texas. Architects: Phelps & Dewees & Simmons, San Antonio, Texas.

Lighting data submitted by Gerard M. Baker and Jack A. Chrismer as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

Efficiency of Flashing Lights: Comparison with Steady-Burning Lights

By THEODORE H. PROJECTOR

In an earlier paper,[1] it was proposed that the computation of the efficiency of a flashing light be carried out in terms of its "effective efficiency," defined by the equation

$$\text{Effective Efficiency} = \frac{Q_{\text{lum}}}{Q_{\text{elec}}} M_{B\text{-}R} \qquad (1)$$

in which Q_{lum} is the luminous energy in the flash, Q_{elec} is the electrical energy producing the flash, and $M_{B\text{-}R}$ is a term designated the "Blondel-Rey Merit Factor." The first part of the expression on the right of equation (1), the ratio $Q_{\text{lum}}/Q_{\text{elec}}$, is the luminous efficiency of the flash. The second part, $M_{B\text{-}R}$, is a measure of the efficiency with which a given quantity of luminous energy is utilized to produce effective intensity in accordance with the Blondel-Rey equation:

$$I_e = \frac{\int_{t_1}^{t_2} I\,dt}{.2 + (t_2 - t_1)} \qquad (2)$$

where I is the instantaneous intensity, t_1 and t_2 are times near the beginning and end of the flash respectively, and .2 is a constant representing approximately threshold viewing conditions. Above threshold the constant decreases.[2] (The generalized form of the Blondel-Rey equation, with the constant a, instead of its threshold value .2, was discussed in earlier papers.[1,2] In this paper, the threshold value will be used because of numerical simplifications that follow from its use, and because of its special importance.)

Douglas[3] has rationalized the computation of effective intensity by maximizing I_e in equation (2). Equation (2) may also be expressed in analogous forms for flux or illuminance. For the purpose of computing efficiency, the flux form is most convenient, and, in this form, with Douglas' rationalization, the Blondel-Rey equation may be written:

$$F_e = \left[\frac{\int_{t_1}^{t_2} F\,dt}{.2 + (t_2 - t_1)} \right]_{\text{max.}} \qquad (3)$$

The Blondel-Rey Merit Factor, $M_{B\text{-}R}$, expresses the effectiveness of utilization of luminous energy in a flash as five times the ratio of the effective flux in the flash to the effective flux of a flash with the same total luminous energy compressed into an extremely short time interval, or

$$M_{B\text{-}R} = 5 \frac{\left[\frac{\int_{t_1}^{t_2} F\,dt}{.2 + (t_2 - t_1)} \right]_{\text{max.}}}{\frac{\int_{t_1}^{t_2} F\,dt}{.2}} \qquad (4)$$

where t_0 and t_3 are times when the instantaneous flux is equal to zero at the beginning and end of the flash, and which include all the flash energy.

Equation (1) reduces to

$$\text{Effective Efficiency} = \frac{F_e}{Q_{\text{elec}}} \qquad (5)$$

(Equation (5), it should be emphasized, is applicable to threshold viewing only. The more general form of the equation requires that the right side be multiplied by the coefficient $5a$. At threshold, $a = .2$, and the coefficient reduces to 1.)

It is often of interest to compare the efficiency of a flashing light with that of a steady-burning light. In some applications, there is an engineering choice between a flashing and a steady light, and the difference in efficiency may be an element of a complete analysis. Whereas the emitted flux of a steady light is a property of the light source independent of the observing conditions, this is not true of the effective flux or the effective efficiency of a flashing light. The effective flux varies with the observing conditions, particularly, as noted above,

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with the illuminance at the observer's eye. The effective efficiency of a steady light compared with that of a flashing light will vary also with the repetition rate of the flashing light. Thus, it is not possible to assign a value of efficiency to a steady light which would be valid for comparison with *any* flashing light, even if threshold or any other fixed viewing condition is understood. If flash repetition rate is subject to control or variation, the relation must be specified for each rate and will, in general, vary considerably with the rate.

Definition

It is proposed that equation (5) be applied to steady-burning lights in order to compute efficiency, with the proviso that the application of the formula must be in a form relating the efficiency of the steady light to a particular flashing light with which it is to be compared. Thus, the "relative effective efficiency" is given by

$$\text{Relative Effective Efficiency} = \frac{\left[\dfrac{F}{Q_{elec}}\right]_{\text{steady light}}}{\left[\dfrac{F_e}{Q_{elec}}\right]_{\text{flashing light}}} \qquad (6)$$

(NOTE: Since the intensity of the steady light is related to its flux in the same way that the effective intensity of a flashing light is related to its effective flux, F is written for the steady light in place of F_e.)

Single, Isolated Flash

If a steady-burning light is compared for efficiency with a flashing light that produces a single isolated flash, then the relative efficiency of the steady light is zero. The numerator of equation (6) is F/Q_{elec}. The electrical energy, Q_{elec}, consumed by the steady light is infinite, since, by definition, the steady light continues to expend energy without limit. The steady light emits flux for an infinite time while the flashing light is dark except for the finite flash interval. If a light visible for only a short time is all that is required in an application, it is infinitely wasteful to continue to burn the steady light when it is not needed.

Another way of looking at this is in terms of equation (1). Here the effective efficiency is defined as the product of the luminous efficiency and $M_{B\text{-}R}$. The luminous efficiency, Q_{lum}/Q_{elec}, of the steady light is a constant ratio, regardless of how long it is burned, and is equal to its luminous efficiency, conventionally given in lumens per watt. $M_{B\text{-}R}$, however, decreases as the steady light is burned longer and longer, approaching zero as the time of burning approaches infinity. The definition of $M_{B\text{-}R}$ compares the effective flux of the light under consideration with the effective flux of a light flash with the same total energy, compressed into an extremely short duration. In the limiting case of a steady light burning for an infinitely long time, the energy consumed, if dissipated in a single short flash, would have an infinitely large effective flux.

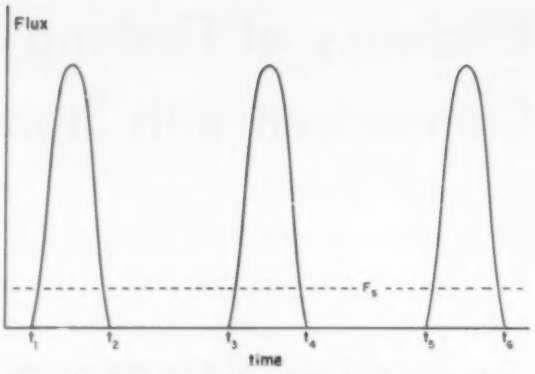

Figure 1. Time distribution of the flux for a repetitively flashing light whose effective efficiency is to be compared wth that of a steady-burning light which is emitting flux F_s.

Repetitive Flashes

In practice, the efficiency of a steady-burning light is not compared with that of a single isolated flash. Rather, the flash is compared with a steady light burning for a finite time or, as the problem is usually presented, the steady light is compared with a repetitively flashing light, as in lighthouses, aircraft "anti-collision" lights, etc. The repetitive flash includes as a special case the single flash as a single cycle of a repetitive flash. The remainder of the discussion, therefore, will be in terms of repetitive flashes.

In Fig. 1, three cycles of a repetitive flashing light are shown. This light is to be compared with a steady light emitting flux F_s. The denominator of the right side of equation (6), which is the effective efficiency of the flashing light, is computed in the manner described previously.[1] F in the numerator, the flux emitted by the steady light, is equal to F_s. Q_{elec} in the numerator is the electrical energy expended by the steady light during one cycle of the flashing light, or the product of the power consumption and the period of the flash, $t_5 - t_3$, for example. Evidently, *as long as the time distribution of flux is not affected*, the relative effective efficiency of the steady light is propor-

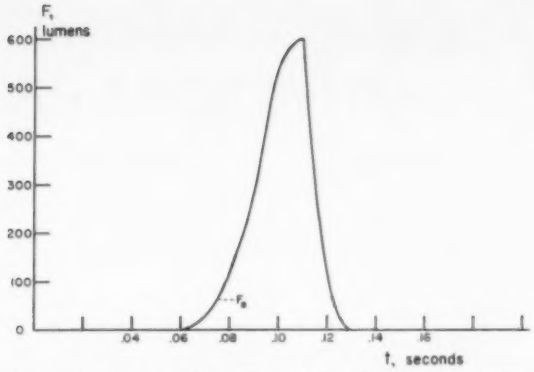

Figure 2. Time distribution of flux for flashing light in Examples 1 and 2.

tional to the repetition rate of the flashing light. If changing the repetition rate of the flashing light changes its time distribution of flux, then it is necessary to recalculate the effective efficiency of the flashing light as well as the steady light in order to obtain the relative effective efficiency appropriate to the new conditions.

Numerical Examples

Example 1

A light with the time distribution of flux shown in Fig. 2 is flashed once every second. The electrical energy consumed is 1.35 watt-seconds per flash. How many watts would be dissipated by a steady-burning lamp with a luminous efficiency of 14 lumens per watt, emitting flux equal to the effective flux of the flashing lamp? What is its relative effective efficiency? (The flashing light in this example is the one used in example 2 of the previous paper,[1] in which it was shown that the effective flux = 65 effective lumens, and the luminous energy per flash = 16.5 lumen-seconds.)

Flashing once per second and consuming 1.35 watt-seconds per flash, the rate at which energy is dissipated by the flashing light is 1.35 watt-seconds per second, or 1.35 watts. It is required that the steady light emit 65 lumens. With an efficiency of 14 lumens per watt, the steady light will dissipate 65/14, or 4.64 watts. The relative effective efficiency is given by equation (6):

$$\text{Relative Effective Efficiency} = \frac{\left[\frac{F}{Q_{elec}}\right]_{\text{steady light}}}{\left[\frac{F_e}{Q_{elec}}\right]_{\text{flashing light}}} = \frac{\frac{65}{4.64}}{\frac{65}{1.35}} = .29$$

or, the steady light is slightly less than $\frac{1}{3}$ as efficient as the flashing light.

Example 2

In the example above it is found necessary to flash the lamp only once every three seconds. What is the relative effective efficiency under these conditions?

Since the steady lamp now consumes $3 \times 4.64 = 13.9$ watt-seconds while the flashing lamp consumes 1.35 watt-seconds, the relative effective efficiency is given by:

$$\text{Relative Effective Efficiency} = \frac{\frac{65}{13.9}}{\frac{65}{1.35}} = .097$$

or, the steady light is slightly less than $\frac{1}{10}$ as efficient as the flashing light. It will be noted that the relative effective efficiency in this case is $\frac{1}{3}$ that obtained in Example 1.

Example 3

A light is flashed repetitively with the time distribution of flux shown in Fig. 3. In one version, the light is not completely occulted between flashes, and, as shown in the figure, emits a constant flux between flashes of 50 lumens. In a second version, the light is occulted between flashes, the flux falling to zero at the beginning and end of each flash at the times corresponding to $t = .06$ and $t = .14$ second for the flash shown in the figure. If the luminous efficiency is 13 lumen-seconds per watt-second, what wattage in a steady-burning light of the same luminous efficiency would match in flux the effective flux of the flashing light when:

a) in version 2, the light is flashed once a second;

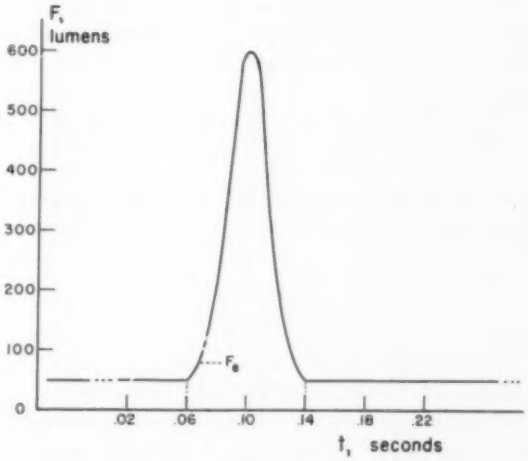

Figure 3. Time distribution of flux for the flashing light in Example 3.

b) in version 1, the light is flashed once a second;
c) in version 1, the light is flashed once every three seconds?

In each of the above cases, what is the relative effective efficiency of the steady light?

By the method of maximization, F_e for the flashing light turns out to be 80 effective lumens, as indicated in the figure. At a luminous efficiency of 13 lumens per watt, the steady light requires 80/13, or 6.2 watts. As Douglas has shown,[3] the maximum value of F_e for the flashing light is obtained if the limits of integration are the times when $F = F_e$, or

$$F_e = \left[\frac{\int_{t_1}^{t_2} F\,dt}{.2+(t_2-t_1)}\right]_{\max.} = \frac{\int_{.068}^{.132} F\,dt}{.2+(.132-.068)} = 80$$

(The same value of F_e would be obtained if F fell to zero at $t = .068$ and at $t = .132$. Thus the flux emitted between flashes, 50 lumens, may be considered "wasted" since it contributes nothing to F_e. We should expect therefore to find the effective efficiency of the flashing light less in case b than in case a.)

In case a, the flux emitted during one flash cycle is contained entirely between $t = .06$ and $t = .14$, for the cycle shown in the figure. From equation (4)

$$M_{B\text{-}R} = \frac{F_e}{Q_{\text{lum}}} = \frac{80}{\int_{.06}^{.14} F\,dt} = \frac{80}{22} = 3.6 \text{ eff lum/lum-sec}$$

Since the luminous efficiency is given by:

$$\text{Efficiency}_{\text{lum}} = \frac{Q_{\text{lum}}}{Q_{\text{elec}}}$$

$$Q_{\text{elec}} = \frac{Q_{\text{lum}}}{\text{Efficiency}_{\text{lum}}} = \frac{22}{13} = 1.69 \text{ wt-secs}$$

$$\text{Effective Efficiency} = \frac{F_e}{Q_{\text{elec}}} = \frac{80}{1.69} = 47 \text{ eff lum/wt-sec}$$

and the relative effective efficiency of the steady lamp is:

$$\frac{\left[\frac{F}{Q_{\text{elec}}}\right]_{\text{steady light}}}{\left[\frac{F_e}{Q_{\text{elec}}}\right]_{\text{flashing light}}} = \frac{\frac{80}{6.2}}{\frac{80}{1.69}} = .27$$

In case b, the conditions are the same as for case a except that "waste" flux is emitted between flashes. Q_{lum} for the flashing light is therefore larger, Q_{elec} is larger, and $M_{B\text{-}R}$ is smaller.

$$Q_{\text{lum}} = \int_0^1 F\,dt = \int_{.06}^{.14} F\,dt + 50(1-.08)$$
$$= 22 + 46 = 68 \text{ lum-sec}$$

$$Q_{\text{elec}} = \frac{Q_{\text{lum}}}{\text{Efficiency}_{\text{lum}}} = \frac{68}{13} = 5.2 \text{ wt-sec}$$

$$M_{B\text{-}R} = \frac{F_e}{Q_{\text{lum}}} = \frac{80}{68} = 1.18 \text{ eff lum/lum-sec}$$

$$\text{Effective Efficiency} = \frac{F_e}{Q_{\text{elec}}} = \frac{80}{5.2} = 15.4 \text{ eff lum/wt-sec}$$

The relative effective efficiency of the steady light is

$$\frac{\left[\frac{F}{Q_{\text{elec}}}\right]_{\text{steady light}}}{\left[\frac{F_e}{Q_{\text{elec}}}\right]_{\text{flashing light}}} = \frac{\frac{80}{6.2}}{\frac{80}{5.2}} = .84.$$

In case c, the conditions are the same as for case b, except that the repetition rate is one flash every three seconds. For the flashing light we have:

$$Q_{\text{lum}} = \int_0^3 F\,dt = 22 + (2.92 \times 50)$$
$$= 22 + 146 = 168 \text{ lum-sec}$$

$$Q_{\text{elec}} = \frac{Q_{\text{lum}}}{\text{Efficiency}_{\text{lum}}} = \frac{168}{13} = 12.9 \text{ wt-sec}$$

$$M_{B\text{-}R} = \frac{F_e}{Q_{\text{lum}}} = \frac{80}{168} = .48 \text{ eff lum/lum-sec}$$

$$\text{Effective Efficiency} = \frac{F_e}{Q_{\text{elec}}} = \frac{80}{12.9} = 6.2 \text{ eff lum/wt-sec}$$

For the steady light, the electrical energy consumed during the three-second period of the flashing light cycle is given by:

$$Q_{\text{elec}} = 6.2 \times 3 = 18.6 \text{ wt-sec}$$

Therefore, the relative effective efficiency of the steady light is

$$\frac{\left[\frac{F}{Q_{\text{elec}}}\right]_{\text{steady light}}}{\left[\frac{F_e}{Q_{\text{elec}}}\right]_{\text{flashing light}}} = \frac{\frac{80}{18.6}}{\frac{80}{12.9}} = .69.$$

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"Invisible" Lighting For SAGE System

By SAMUEL A. FRANCIS
WILLIAM H. AYER
GEORGE E. HAWKINS

Modern technology is producing many weapon systems whose performance has pushed nearly to a limit the capabilities of human operators. It has long been recognized that, in a modern manned interceptor, elaborate means are required to protect the pilot and provide him with an environment in which he can survive and operate efficiently. In the design of complex ground systems, such as the Air Defense Command's SAGE system for air defense, it is equally necessary to provide an environment in which humans can operate with optimum efficiency.

In the design of the SAGE system, which was conceived by the MIT Lincoln Laboratory, human factors received primary consideration in all phases of equipment and facilities design. One of the factors which received considerable attention was the visual environment in operational areas.

Since World War II, when the first radar sets were put into operational use, the desirability of improving the working environment has been obvious. Typically, radar installations have required a dark room with the only light coming from the illuminated controls on the consoles and numerous poorly shielded lamps for reading and writing. In addition, an edge-lighted plastic plotting board for a larger scale presentation of the radar information has often held a prominent position in the room. These light sources have proved to be extremely annoying as to brightness ratios with surrounding dark areas. They also detract from scope legibility, often producing a bright specular or mirror-like reflection on the scope face. A dark adaptation problem also exists in entering such a room from a normally lighted area.

Research efforts aimed at alleviating these condition were undertaken by the Air Force, Signal Corps and the Navy in this country, and by similar organizations in Great Britain and other countries. The basic concept of the Broad Band Blue Lighting System was formulated by the Ohio State University Research Foundation for the Wright Air Development Center. This concept was further refined and adapted for use in the SAGE system jointly by staff members of the Lincoln Laboratory and Francis Associates, while the latter were working as consultants to the Lincoln Laboratory.

The SAGE system display consoles are similar to the familiar radar PPI (Plan Position Indicator) equipment except that they utilize a 19-inch charactron display tube with a P-14 or P-7 phosphor in place of the regular 14-inch cathode ray tube. They also contain a large number of pushbutton switches for communicating with the high-speed digital computer that forms the heart of the SAGE system. The console operator is faced with several tasks requiring different levels of illumination. First and foremost, he must be able to read a flashing display, somewhat similar to a regular radar picture, but randomly displayed across the face of the scope instead of generated by a rotating scan. The display is not continuous, but is periodically intensified and allowed to decay. His secondary tasks include the operation of the appropriate switches, use of dial telephone equipment, reading of maps or printed material, note taking and, in some cases, supervision of other personnel in the room. It is obvious that the lighting requirements for these secondary tasks could well be in conflict with the primary requirement of display legibility. This conflict led to the development of the SAGE Broad Band Blue Lighting System.

Four specific requirements were set for the desired system. Most important, display legibility must not be degraded by the lighting system. Second, there must be enough ambient light in the room to permit reading clearly printed material and normal writing or note taking. Third, there should be enough general illumination for freedom of movement and proper supervision of personnel. Finally, the lighting system should minimize fatigue and cause as little operator discomfort as possible.

To fulfill these requirements, the design effort was directed toward two goals: reduction of non-

Authors: Francis Associates, Consulting Engineers, Marion, Mass.

specular reflectons from the phosphor and elimination of specular or mirror-like reflections on the scope face and implosion shield.

Reduction of Non-Specular Reflections

Several techniques have been devised to permit raising the level of general illumination in an operational area without serious degradation in the legibility of a cathode ray tube. These include use of polarized light and several restricted spectrum systems, such as the sodium-yellow, the mercury-minus-red and the broad-band-blue system. These systems all utilize a restricted spectrum or polarized filter over the light source and another filter which, due to its spectral transmission or polarization, excludes room illumination from the cathode ray tube, but allows the signal from the scope to be transmitted.

Two major factors affecting cathode ray tube legibility are the absolute value of the display signal brightness and the ratio of display signal brightness to background brightness on the scope face. The signal brightness is often variable, as in the case of a search radar display. In the SAGE system, however, all displays are generated by the computer and are of equal initial brightness. The exact point of compromise between the signal to background ratio and the brightness of the signal itself depends on the display system. In this particular application, the signal level is relatively weak, because of the large quantity of information which must be displayed in a given time. Tests run by the Psychology Group of the Lincoln Laboratory on a small group of subjects, plus equipment considerations, indicated that the compromise under these conditions should favor the signal strength rather than the ratio of signal to background brightness. The importance of this point lies in the possibility that a more effective lighting system might be achieved if a greater signal brightness were available.

Since the displayed signal brightness was essentially a constant, the major requirement became that of increasing the level of room illumination without substantially degrading the signal strength or increasing the background brightness of the scope. Since the signal from the phosphor lies in the yellow-green region, a low pass filter that is transparent to these colors could be placed in front of the scope face without serious attenuation of the displayed signal. If the room lighting is confined to another part of the specrum, such as the blue end by a band pass filter, it will not pass through the scope filter and therefore will not illuminate or activate the phosphor. This technique is known as the Broad Band Blue System, due to the appearance of the room illumination. Earlier versions of this system used standard Air Force orange and blue filters originally designed for instrument flying practice. Its adoption for the SAGE system led to further refinements in the use of these complimentary filters, which are now available commercially.

The exact choice of filters was governed by the spectral characteristics of the phosphor, the spectral output of the fluorescent lamps, the required compromise between the signal-to-background brightness and the signal strength, and the availability of suitable band pass and low pass filters. Appropriate curves showing the inter-relationships of these functions are shown in Fig. 1. The P-7 phosphor curve (Fig. 1a) shows only the persistent part of the signal and not the initial blue flash, which lasts only during the 25 microseconds while the beam is generating a particular character or symbol on the tube face.

The important feature of the yellow filter curve is that it is chosen with a sufficiently low cut-off to pass essentially all the persistent signals from the P-7 phosphor. In this way, the full strength of the display signal is allowed to pass through to the operator with little more loss than with a completely transparent plastic or glass implosion screen.

The choice of a suitable blue filter is restricted by the availability of suitable blue dyes and by the inefficiency of standard fluorescent lamps in the blue portion of the spectrum. For these reasons, the blue filter chosen produces some light in the green region that can pass through the yellow filter, reducing somewhat the signal-to-background brightness radio. This ratio could be improved by using a narrower band pass blue filter if the density of the blue dye or the thickness of the filtering plastic could be increased. Unfortunately, such an increase would lead to a lowering of the illumination level obtainable with any reasonable number of lamps. The blue light output seen by the human eye is only 4 or 5 per cent of the total light available if no filters were used. This can be seen in Fig. 1, by comparing the area under the room illumination curve, R, with the area under the daylight fluorescent lamp curve, I. This room illumination curve is obtained by multiplying the fluorescent lamp output curve by the blue filter characteristic and the correction factor, E, for the human eye.

The amount of room illumination that passes through the scope filter and is reflected back through the filter to be observed by the operator is too small to be indicated in Fig. 1. Its value is $T = R \cdot Y^2$.

Two secondary advantages result from the relatively wide band width of the selected filters. There is a characteristic reaction by most people to narrow

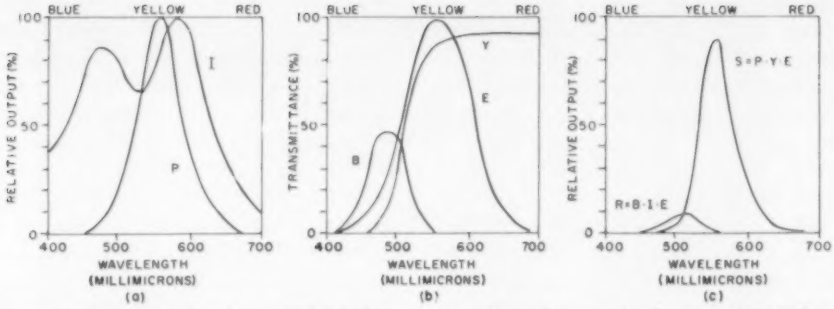

Figure 1. The spectral output, *I*, of a standard daylight fluorescent lamp and the unfiltered output, *P*, of a P-7 phosphor, exclusive of the initial blue flash, are shown in (a). The transmission characteristics of the blue, *B*, and yellow, *Y*, filters used are indicated in (b), along with the characteristic response curve for the human eye, *E*. The resulting filtered room illumination, *R*, and transmitted scope signal, *S*, as seen by the human eye, are shown in (c). It should be noted that the peak values of curves *R* and *S* have no relation to the actual amount of illumination or signal strength which results, but only the relative attenuation of the spectral outputs, *I* and *P*.

band monochromatic light, leading to complaints of nausea and dizziness. This effect is alleviated as the band width of the light is increased. In the case of the SAGE blue, the over-all effect is slightly strange or unnatural compared with daylight or the artificial illumination to which people are accustomed. The small minority, however, that complains initially about the color appears to adjust to it after two or three visits of 15 or 20 minutes each. The majority of people, after long exposure, experiences no discomfort.

The low cut-off of the yellow filters allows the use of simple circuits in the "light gun," a photocell device used by an operator to indicate a particular piece of data to the computer. Since it works on the initial blue-green flash rather than on the persistent yellow signal from the phosphor, any further reduction in transmission of the scope filter at the blue end would require more sensitive and complicated circuitry.

Physically, the yellow scope filter is a ¼-inch thick flat sheet of Plexiglas, mounted directly in front of the face of the charactron display tube, as shown in Fig. 2. In this way it also serves as the customary implosion screen to protect the operator.

The blue filters consist of extruded Plexiglas tubes that slide over standard 40-watt daylight fluorescent lamps. Molded rubber caps are used to hold the filters securely and seal them at the ends of the lamps to prevent leakage of white light.

Specular Reflections

With a higher level of room illumination, the specular reflections from the surface of the yellow filter implosion screen had to be significantly reduced. This was primarily a mechanical or physical problem which could be resolved by careful shielding of the light sources and control of brightness and brightness contrasts in the room. The most direct, but unfortunately the least desirable, approach

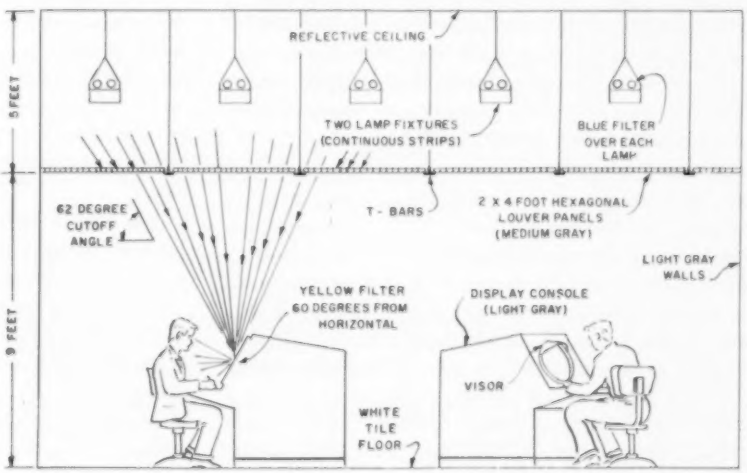

Figure 2. General arrangement of lighting in operational area.

is the use of a closed hood or conical shield over the face of the tube. In addition to the awkwardness of such a device, the necessity of performing the secondary tasks of reading, writing and operation of the scope controls precludes its use for anything but laboratory equipment. It was found, however, that a small visor at the top of the scope would not hinder operation of the controls and could prevent some of the direct light from falling on the scope face. Therefore, a visor extending approximately six inches out from the top of the scope face was added to each console.

The basic philosophy adopted for this phase of the work is that surfaces and objects having both low brightness and low brightness ratios with one another will not create distracting reflections in the scope face visible to the operators. Use of a large uniform low-level source of illumination was necessary if the required brightness ratios were to be realized. Therefore, a totally indirect lighting system was adopted. This, in itself, was not a complete solution, however, since the indirect fixtures appeared as dark rectangles against the reflective ceiling, which was too bright at any reasonable illumination level. It was necessary to shield the entire ceiling area from the scope operator's reflective cone of vision and create a dark, uniform reflection in its place. A diffusing medium such as a suspended plastic ceiling would hide the fixtures, but would still be as bright as the original reflective ceiling for a given illumination level in the room. The use of vertical louvers, allowing vertical light rays to pass into the room while blocking the more horizontal rays which would appear as reflections in the scope, resolved this difficulty. If the cut-off angle or thickness of the louvers is chosen properly all the operator will see as a reflection on the yellow filter are the sides of the louvers. Painting the louvers a suitable shade of gray will then create the impression of a dark unlighted ceiling to the operator. Therefore, the cut-off angle of the louvers was chosen as 62 degrees, since the average small man cannot see reflections at an angle greater than this from a normal viewing position. This geometry is illustrated on the display console shown on the left in Fig. 2.

Because the display consoles in the SAGE system are placed in many different orientations, it is essential that the louvers have the same appearance when viewed from any direction. Therefore, hexagonal cell louvers were chosen in preference to square or parallel plane designs. The size of the cells is also significant, since a small cell louver on the order of ¼-inch or so across the flat sides of the cells creates a textured pattern on the scope face which the eye can easily ignore. A larger cell size, on the other hand, causes images of the individual cells on the scope face which are distracting to the operator.

Adoption of a small cell louver introduced new difficulties in design of a suspension system which would not create disturbing images in the scope face. The most satisfactory solution makes use of standard T-bars painted the proper shade of gray, so that the light reflected from the floor causes their lower surface to have the same brightness as as the vertical sides of the louvers. If this matching of surface brightness is proeprly done, the suspension system will blend into the ceiling pattern and be virtually indistinguishable to the scope operator.

Because these louvers are considerably deeper than normal, the slightest lack of uniformity in the light passing through them causes objectionable variations in their brightness when viewed from below. It was found necessary to allow approximately five feet of clearance between the louvers and the reflective ceiling above them to provide the necessary uniformity and prevent shadows of the indirect fixtures from falling on the louvers. When this clearance is unobtainable, a direct lighting system may suffice, but extremely careful engineering and testing are necessary if striping of the louvers is to be avoided.

Once a ceiling with dark appearance is achieved, it is necessary that the upper portion of the walls, also visible to the operator as a reflection, have a similar appearance. In order to obtain maximum utilization of the illumination available, it is desirable that all surfaces not visible to the operator be as light as possible. Thus, the ideal situation is one with a dark ceiling, walls of matching darkness at the top and gradually growing lighter towards the floor, and a light floor. With the direct vertical light rays from the ceiling, this condition will provide the proper distribution of light for reading and ready movement of personnel around the room.

This effect is achieved by careful specification of the reflectance value of all finishes used in the room. Brightness of the upper wall was matched with the brightness of the sides of the louvers directly adjacent by control of the reflectance value of the wall paint. Since more light passing through the louvers strikes the lower portion of the wall, the wall becomes gradually brighter from the ceiling to the floor.

The visual environment created for SAGE was tailored to the specific requirements of that system and has been proved workable. Other systems have different requirements which may require a completely different approach.

The Broad Band Blue environment is currently being incorporated in all SAGE installations and a modified version is planned for the Missile Master System for anti-aircraft defense control.

INSTALLATION AT COLUMBUS AND SOUTHERN OHIO ELECTRIC CO., COLUMBUS, OHIO.

Lighting a General Office

LIGHTING OBJECTIVE: To provide a high level of comfortable illumination for regular office work, which includes occasional blueprint work.

GENERAL INFORMATION: This general office area, which measures 60 feet by 95 feet with a nine-foot ceiling, has the following reflectances and colors for its major room surfaces:

ceiling	white	77% RF	floor	buff	53% RF
walls	light mahogany	29% RF	desk tops	gray	50% RF

INSTALLATION: An average illumination level of 152 footcandles was provided after about 5000 hours of operation by 143 Smitheraft catalog No. PAN 3-40S troffer units, each equipped with three 40-watt T-12 cool white lamps. These units are recessed in continuous rows on six- and seven-foot centers in a metal pan ceiling supported by T-bars.

Brightness readings after about 5000 hours' operation were:

luminaires			
at 45 degrees crosswise	942 fL (maximum)	ceiling	45 fL
at 30 degrees crosswise	406 fL (maximum)	walls	25 fL
at 45 degrees lengthwise	695 fL (maximum)	floor	86 fL
at 30 degrees lengthwise	532 fL (maximum)	desk top	78 fL

Lighting designed by Columbus and Southern Ohio Electric Co.; Contractor: Electric Power and Equipment Co., Columbus, Ohio.

Lighting data submitted by B. D. Russell, Commercial Lighting Supervisor, Columbus and Southern Ohio Electric Co., Columbus, Ohio, as an illustration of good lighting practice and to aid in the design of similar installations.

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A.I.A. File No. 31

I.E.S. Guide for

Reporting General Lighting Equipment Engineering Data

Prepared by the Subcommittee on Guide for Reporting Lighting Equipment Engineering Data of the Committee on Testing Procedures for Illumination Characteristics

Foreword

A suggested report form for the presentation of performance data on lighting equipment,[1] prepared by the I.E.S. Committee on Testing Procedures for Illumination Characteristics and the Committee on Illumination Performance Recommendations, appeared in the August 1949 issue of ILLUMINATING ENGINEERING. It was the intent of the committees that the proposed form be used as a guide by manufacturers and testing agencies in preparing forms for the presentation of photometric and other pertinent data on lighting equipment.

In the years since this publication, the committees involved have received numerous suggestions for improvements upon the original guide. Also, some sections of the form proposed in 1949 have since become inapplicable. In view of this, the following revised guide is now submitted.

SUBCOMMITTEE ON GUIDE FOR REPORTING LIGHTING EQUIPMENT ENGINEERING DATA

E. H. Witte, *Chairman*

R. D. Burnham — J. H. McCulloch — R. P. Teele

COMMITTEE ON TESTING PROCEDURES FOR ILLUMINATION CHARACTERISTICS

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T. H. Leister — Peter L. Young

Approved by the Council of the Illuminating Engineering Society, March 1958. A Transaction of the IES.

1. Purpose and Scope of Guide

(a) It is not the purpose of this guide to establish a standardized report form. It is the intention of the committee only to provide a reference guide for use in the design of report forms, suggesting a practical format and terminology for presenting the information obtained from a typical photometric test.

(b) No attempt has been made in this guide to discuss test reports for anything other than general lighting luminaires. The manner of reporting test data on floodlights, streetlighting luminaires and other specialized equipment can be more effectively treated in the I.E.S. guides on testing procedures.

2. General Information

(a) The subject matter of a photometric test report can be roughly divided into three areas: general information, photometric data and application data. The application data may include coefficients of utilization, comfort ratings, recommended maintenance factors and similar information. The photometric data would be the candlepower distribution data, lumen output values, brightness figures, etc. The general information provides the background material for the other two categories and is therefore of vital importance.

(b) Fig. 1 shows the minimum general information which should be included. The first requirement is a descriptive title to indicate what is being reported. The names of the manufacturer and testing agency, the report number and date of test are important information and should always be shown.

(c) A detailed description of the item tested should always be included. The luminaire (or lamp) should be listed both by its trade name, if any, and its official designation such as the catalog number, sample number, etc. This description should give a clear picture of the type of luminaire, such as "Porcelain enamel, open-end industrial luminaire

Lighting Equipment Engineering Data

Manufacturer's Company Name

Laboratory ..... **Date** ..... **Report No.** .....

Luminaire ..... **Designation** .....

General Description .....

Reflectances ..... **Transmittances** .....

Lamps .....
(Number, type & watts each)

Rated Lumens Each ..... **Rated Brightness** .....

Auxiliary Equipment .....

Classification: CIE ..... **IES** .....
(Direct and Semi-Direct Luminaires)

This report is based on test methods in accordance with I.E.S. Guides to Testing Procedures.

Figure 1. Illustration of general information which should be included in report.

with apertures" or "Surface-mounted commercial luminaire with white painted metal sides and plastic louvers." Reflectance and transmittance figures should be given for all light controlling parts including reflectors, louvers, center shields, cover glasses, etc.

(d) The description of lamps should consist of the number, type, rated watts, rated lumens per lamp, rated brightness, color, bulb shape and any other information which relates to the performance of the luminaire or the interpretation of the test results. Auxiliary equipment, insofar as it could affect the results of the test, should be described in detail.

(e) Classification of the luminaires by distribution using the C.I.E. (formerly I.C.I.) system is widely recognized and should be shown. The I.E.S. classification,[2] based on the spacing-to-mounting height ratio should be included for direct and semi-direct luminaires.

(f) In any case where the data presented on a test report could be substantially different than the actual performance of a luminaire when operated on the premises of the purchaser, the possibility of this variance should be clearly stated on the report. For instance, in the photometric testing of fluorescent luminaires, if done in accordance with the I.E.S. Guides to Testing Procedures,[3] all candlepower and lumen values are based on the assumption that the lamps are delivering their rated lumen output. This leads to a photometric test report which is entirely independent of ballast and lamp performance. In this and similar cases it is recommended that the report contain an explanatory statement such as the following:

> "This report is based on a nominal rating of _____ lumens per lamp. In service performance is materially influenced by ballast characteristics, lamp efficacy, ambient temperature, operating position and luminaire condition, all of which may differ from the actual test conditions."

3. Distribution Curve and Data

(a) The presentation of candlepower distribution data can be done graphically with candlepower curves, with tabulated data or with both. If the distribution curve is to be the primary source of information it should be large enough, and accu-

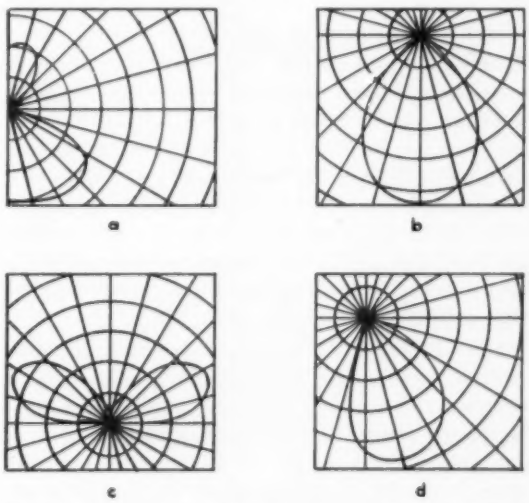


Figure 2. Several useful arrangements of polar charts.

VERT. ANGLES	CANDLEPOWER PLANE OF MEASUREMENT					ZONE	ZONAL LUMENS
	0°	22½°	45°	67½°	90°		
180°							
175°						170°-180°	
165°						160°-170°	
155°						150°-160°	
145°						140°-150°	
135°						130°-140°	
125°						120°-130°	
115°						110°-120°	
105°						100°-110°	
95°						90°-100°	
90°							
85°						80°-90°	
75°						70°-80°	
65°						60°-70°	
55°						50°-60°	
45°						40°-50°	
35°						30°-40°	
25°						20°-30°	
15°						10°-20°	
5°						0°-10°	
0°							

TEST DISTANCE _____ FEET

Figure 3. Tabulation of candlepower and lumen data. Space for different or additional planes may be provided. (0 degrees is the longitudinal axis.)

ZONE	LUMEN SUMS	PER CENT BARE LAMP	PER CENT LUMINAIRE
0°-30°			
0°-40°			
0°-60°			
90°-180°			
0°-180°			
EFFICIENCY OF LUMINAIRE:			

Figure 4. Tabulation of lumens in major zones. (Zones other than those shown may be preferred.)

rate enough to provide reliable information. The center of the polar web may have any of several positions, depending upon the type of unit tested. (See Fig. 2.)

(b) The distribution curve serves as a "picture" of luminaire performance and while this is all that is needed in many cases, the laboratory that supplies the report can never foresee what additional uses may be made of the candlepower data. The plotting and reading of rapidly changing and relatively small candlepower values from a polar diagram becomes imprecise. Tabulation of candlepower data is accordingly much to be desired. Current emphasis on computations of comfort requires that data at high angles be quite reliable.

(c) Tabulated data should be comprehensive enough to satisfy the needs of all possible users of the report. Candlepower data should be shown for all planes tested in the case of luminaires with a non-uniform distribution. Averaged candlepowers, useful only for computing zonal lumens, need not be shown where zonal lumens are tabulated. Ordinarily the candlepower would be shown in ten-degree steps, but in the case of luminaires with narrow or irregular distributions, it may be necessary to use five-degree or even smaller steps to give a complete picture. The advisability of printing particular angles on the report form (see Fig. 3) rests on the likelihood of different zones often being used.

(d) A tabulation of zonal lumens as shown in Fig. 3 is especially important since the adoption of the zonal method of calculating coefficients of utilization. A progressive summation of lumens may be included, but should be in addition to the tabulation of lumens in each ten-degree zone as shown in Fig. 3.

(e) Fig. 4 shows a tabulation of total lumens in various significant zones. While this information could easily be calculated from the information shown in Fig. 3, it is a convenience to the user to have it already given. Since the zones selected could vary, the zone designations would not normally be printed on a report form intended for general use.

4. Brightness Data and Shielded Zones

(a) The brightness data to be reported is in many cases determined by the I.E.S. guides on testing procedures for the various types of luminaires. These normally recommend that the maximum brightness in various zones be measured. When this is the case, the block for reporting brightness data would include a column for the zones, a column for the angle within these zones at which the maximum brightness occurred, a column for the

SHIELDED ZONES BELOW HORIZONTAL
CROSSWISE ____ LENGTHWISE ____

ZONE	MAXIMUM BRIGHTNESS IN FOOTLAMBERTS					
	CROSSWISE			LENGTHWISE		
	B	ANGLE	APER.*	B	ANGLE	APER.*

*DIMENSIONS OF TEST INSTRUMENT APERTURE FOR CANDLES/SQ IN. DIVIDE VALUES ABOVE BY 452

Figure 5. Possible arrangement for tabulating brightness data and shielded zones.

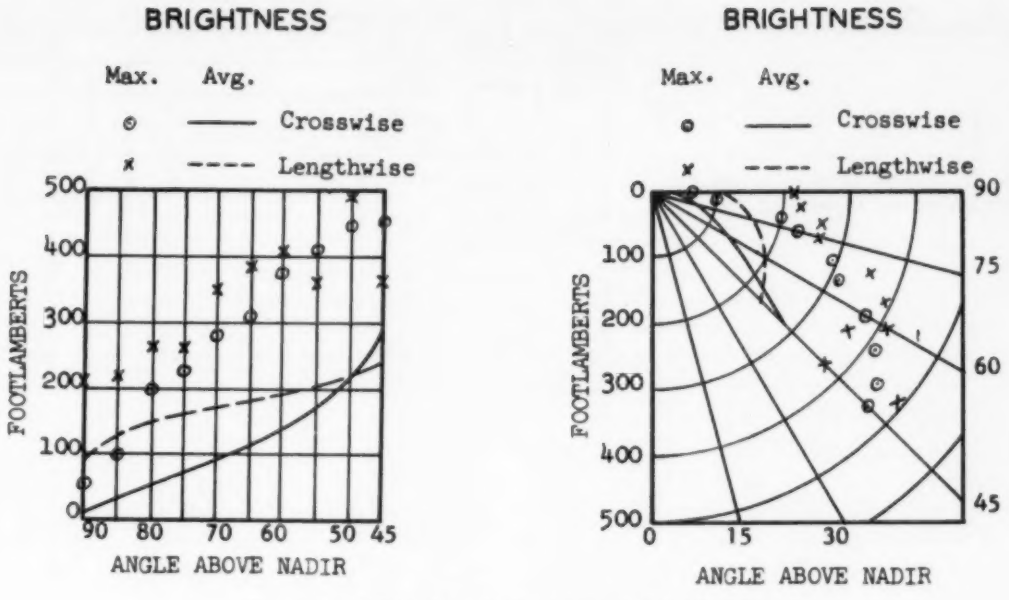


Figure 6. Graphical methods of reporting brightness.

actual brightness and a column for the dimensions of the test instrument aperture.* Fig. 5 shows a possible arrangement for this information.

(b) An alternate (or supplementary) method of presenting brightness data is that shown in Fig. 6. Here the brightness values are given graphically on a coordinate system with brightness values plotted against the angle of measurement. While this method of presentation makes it slightly more difficult to read the maximum brightness within a particular zone, it certainly simplifies the recording of average brightness values (curves of Fig. 6) where these are to be included. The rectangular plot is favored as eliminating possible confusion with polar candlepower distribution curves.

(c) The actual brightnesses can be given in terms of candles per square inch or in footlamberts. The unit used should be plainly shown and the conversion factor should also be shown. As shown in Figs. 5 and 6 the direction of measurement should be given in terms of the angle from nadir (straight down) rather than the angle below the horizontal.

(d) The term "shielded zones" refers to the zone or zones over which the light source is shielded from direct view. Recommended practice is to list the shielding angles in terms of degrees below the horizontal.* When an intermittent shielding condition exists, it should be reported. With most fluorescent luminaires two shielding angles are given, the crosswise shielding and the lengthwise, and reported in that order. With some luminaires it may be desirable to report the shielding to the light center, lower tip of luminous arc, or lower edge of phosphors with mercury lamps, and possibly the tip of the bulb in the case of inside frosted lamps. However the shielding is measured, it should be completely described in the report. The luminaire element providing the shielding should be identified in the sketch of the luminaire.

5. Application Engineering Data

(a) This section of the report, together with the candlepower distribution data is the most important part of the report for the majority of users. The form shown in Fig. 7, already in use by some manufacturers, is offered as a good example. Information calculated by others from data supplied by a testing agency should be labeled as such.

(b) The Zonal Factor Interflectance Method of calculating coefficients of utilization has been officially approved by the Council of the Illuminating Engineering Society.[4] Since it may be some time before all existing data have been revised, a notation should be made as shown in Fig. 7 indicating

*Whether or not there exists an established guide covering the particular test being reported, it is sound practice to include information on the measuring instrument. In the absence of a universally accepted standard practice for the measurement of brightness, it is often important to the technical reader to know the aperture dimensions.

*The shielding of filament industrial reflectors was formerly specified as a cut-off angle measured from nadir. Cut-off and shielding angles are complementary; their sum always adds up to 90 degrees.

Figure 7. Example of form for tabulating application engineering data.

APPLICATION ENGINEERING DATA																
DISTRIBUTION	SPACING NOT TO EXCEED	FLOOR REFLECTANCE														
% RARE LAMP ↑ / ↓		CEILING REFLECTANCE														
	X	WALL REFLECTANCE														
	MOUNTING	ROOM INDEX	ROOM RATIO	COEFFICIENTS OF UTILIZATION												
	HEIGHT	J	0.6													
		I	0.8													
CIE % LUMINAIRE	MAINTENANCE FACTORS	H	1.0													
		G	1.25													
↑ / ↓	GOOD:	F	1.5													
		E	2.0													
		D	2.5													
	MED.:	C	3.0													
		B	4.0													
	POOR:	A	5.0													

Coefficients of utilization computed by Zonal Factor Interflectance Method as approved by IES (1953 & 1955)

the method of calculation. For the same reasons, it is suggested that coefficient of utilization tables covering lamps with integral reflectors bear notation to the effect that the coefficients are based on the lumen output of the processed lamp in keeping with recommended I.E.S. practice.[5] The room surface reflectances for which coefficients of utilization are calculated may vary depending upon the application and the type of luminaire. The values used, however, should include those listed in the tables shown here as the minimum number suggested by the I.E.S. Lighting Design Practice Committee.[4]

Industrial Luminaires
10 Per Cent Floor Reflectance

Ceiling Reflectance (per cent)	70			50			30	
Wall Reflectance (per cent)	50	30	10	50	30	10	30	10

Other Than Industrial Luminaires
10 Per Cent Floor Reflectance

Ceiling Reflectance (per cent)	80			70			50		
Wall Reflectance (per cent)	50	30	10	50	30	10	50	30	10

(c) The form shown in Fig. 7 contains a column titled "Room Ratio" adjacent to the Room Index column showing the room ratio values for which the coefficients were calculated. Inclusion of this information will have a double benefit. First, it will serve to remind the user that the room indexes are more than mere letters, they have a definite mathematical source. Second, it will simplify interpolation when the user desires a higher degree of accuracy than is provided by the room index letters.

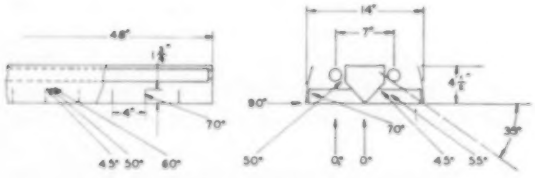


Figure 8. Example of sketch of luminaire.

(d) The manufacturer should provide suggested maintenance factors and although the information may be shown elsewhere, a space showing upward and downward distribution data in the form illustrated at the left of Fig. 7 is often a convenience to the user. The maximum spacing-to-mounting height ratio for direct and semi-direct luminaires should be shown and should be calculated in accordance with standard I.E.S. procedure.[2]

6. Sketch of Luminaire

A sketch of the luminaire tested is an important part of the report. It is recommended that this sketch be as realistic as possible (see Fig. 8), showing over-all dimensions, dimension of louvers and shields, location and spacing of lamps, etc. The points and angles at which maximum brightness reading were made may be shown here with arrows indicating the angle of measurements and extending as closely as possible to the luminaire part whose brightness was measured.

References

1. Committee on Illumination Performance Recommendations of the I.E.S., "Lighting Equipment Engineering Data Sheet," ILLUMINATING ENGINEERING, Vol. XLIV, No. 8, p. 482 (August 1949).
2. Committee on Illumination Performance Recommendations of the I.E.S., "Classification of Luminaires by Distribution," ILLUMINATING ENGINEERING, Vol. XLIX, No. 11, p. 552 (November 1954).
3. Committee on Testing Procedures for Illumination Characteristics of the I.E.S., "I.E.S. Guide for the Photometric Testing of Fluorescent Luminaires," ILLUMINATING ENGINEERING, Vol. XLIV, No. 7, p. 413 (July 1949).
4. Committee on Lighting Design Practice of the I.E.S., "Calculating Coefficients of Utilization," ILLUMINATING ENGINEERING, Vol. LI, No. 5, p. 385 (May 1956).
5. Committee on Lighting Design Practice of the I.E.S., "Uniform Methods of Presentation and Calculation of Room Index, Coefficients of Utilization and Maintenance Factors," approved by the Council of the Illuminating Engineering Society February 1950, not published.

Views and Opinions

New IES Footcandle Levels In Residences

One of the problems in residential lighting studies is the fact that there are nationally very few experienced persons, relative to other lighting fields, who make illumination measurements either in an accurate manner or in accordance with methods set forth by the Society. For this reason many people may believe the attainment of the new recommended levels for homes is more simple than it is. The levels can be attained if little or no attention is paid to lighting quality. However, portable lamps and fixtures of typical designs on the market using appropriate available light sources will not supply the recommended footcandles for the more critical visual activities that are stated as "minimum on the task at all times." For example, on a study desk the 200-watt filament of a 50/200/250-watt bulb in an 8-inch CLM bowl and an accurately proportioned and placed table lamp, will give an *average* of 70 footcandles on the test plane. However, on that side of the plane away from the lamp, it is not possible to obtain the specified 70 footcandles. And if we are to apply a mere 10 per cent for a depreciation factor, the initial lowest footcandle reading should be 77! Two such desk lamps, using 200 watts each, would supply the demanded footcandle level in time and space, but this becomes an impracticable recommendation for use with all but large desks.

We have been able to attain on an *average* basis (not on the basis of the recommended level everywhere on the task at all times) the new footcandles for typical critical and prolonged tasks in a family room by the use of slightly under 10 watts per square foot. The area is about 280 square feet, wall reflectances near 40 per cent, floor 30 per cent, ceiling 70 per cent. The installation includes five well designed local luminaires augmented by fluorescent wall lighting on four walls and eight downlights. The comfort in the room is high. Cost is far beyond what the industry has yet been able to sell to the majority of home owners.

In a small living room, about 170 square feet with high wall and ceiling reflectances, we have obtained average levels only between 30 and 50 (fc) at four reading positions and 100 at one sewing position, with a total of 8.5 watts per square foot, all incandescent and all five equipments typical of current good design. It must be pointed out that comfort is not good in the room and the effects not as emotionally acceptable as in the above darker walled and larger room.

It will take considerable time before the recommended levels, at least those above 30 or at most 50 footcandles, are *widely* accepted or can be put into practice generally, except possibly in the utility areas. To meet the new standards, new equipment designs will need higher output sources and/or new arrangements for multiple sources. The following considerations should be borne in mind:

1. The history of residential lighting in the past 30 years emphasizes the "snail's pace" of progress. Even with the national BLBS and LBE promotions, less than 15 per cent of the homes today will meet the previous IES standards published for over ten years. Currently 62 per cent of American homes have less than a total of 25 bulbs in six rooms (approximately 75 bulbs are required to meet the 1953 IES Practice and it is assumed more will be required for the new levels).

2. New equipments and very likely light sources will have to be designed to produce realistically and comfortably the levels demanded (minimum on tasks at all times). If presently available equipment of the best designs for lighting performance is augmented by lighting elements built-in or on the house structure, the standards can be met. To date the costs involved have not been accepted by the *average* home owner or builder.

3. With incandescent bulbs, heat problems are going to increase in typical portable lamps. Today the 300 watts in the three-way lamp represents the maximum lumens attainable from a single bulb and these do not produce the required footcandles for critical work. There is already some objection to the heat from the use of 300 watts.

4. Experience indicates that many families feel that the atmosphere of the home should have a relaxing and emotional appeal and should be very different from the work world. Very generally low light levels are thought to be synonymous with the "homey" environment. In the best installations which met the previous IES standards, provision was always made so that low levels were obtainable when critical visual work was not being done.—MARY E. WEBBER, *General Electric Co., Nela Park, Cleveland, Ohio.*

American Delegates
Seen Between Sessions at CIE

John Chorlton (Canadian delegate), R. P. Teele, Art Barr

Foster Sampson, Professors P. F. O'Brien, E. M Strong

Bob Carson, R. C. Putnam

Laurence Harrison, L. C. Twichell

S. K. Guth with Dr. Ward Harrison

Ruby Redford, Mrs. R. P. Teele, Mrs. J. W. Young

Bill Griffith, Dorothy Nickerson

LIGHTING NEWS

International Aspects of Lighting
CIE Congress, Brussels, June 15-24

Delegates from 24 countries convened in Brussels in June for two weeks of extensive interchange of lighting information. The occasion was the 14th Session (one every four years) of the Commission Internationale de l'Eclairage (International Commission on Illumination) held at the Palais du Congrés in Brussels, June 15-24. Fifty-two of the 500 delegates attending the Congress were from the United States, all of these IES members. The United States National Committee, which for years has been an active and respected part of this international group of lighting experts, is headed by Herbert H. Magdsick, President; L. E. Barbrow, National Bureau of Standards, Secretary; Willard Brown, General Electric Co., Vice-President, and T. D. Wakefield, Wakefield Lighting, Inc., Treasurer. Americans attending this meeting were afforded a most valuable and rewarding opportunity of seeing and discussing advances in lighting all over the world, both scientific and application. The USNC cordially invites further membership and participation in its work in international lighting affairs.

During the first week of the Session, parallel meetings were held, at which 16 Committees of Experts, who work continuously in the fields of activity assigned to them, reported on the progress and status of their work. Also, 13 Secretariat Committees reported on the advances which have been realized in their fields in all parts of the world during the past four years, and presented bibliographs covering that period. All of the sessions, committee reports and papers were translated simultaneously by multi-lingual translators into the three official languages of CIE — French, English and German. The splendid new Palais du Congrés in Brussels is equipped for this service, with sound-proof translator booths, ear phones and microphones at each seat, as in the United Nations. Thus, session chairmen, speakers and discussers from the audience may make all their remarks in a language familiar to them. Belgian Committee uniformed hostesses were prepared to assist delegates in any of eleven languages, including Arabic.

Three of the reports of Committees of Experts were prepared and presented by United States Chairmen. These were the Secretariats on: Colorimetry — D. B. Judd, Chairman; Causes of Discomfort in Lighting — S. K. Guth, Chairman, and Airborne Lighting — T. M. Edwards, Chairman.

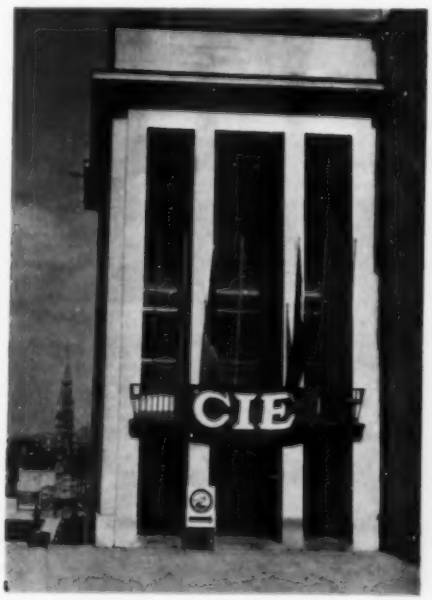
American delegates were also assigned by the USNC to "cover" each of the other Secretariat reports and working committee sessions, for a report on other countries' work to the United States Caucus held at the end of each day's sessions, and to speak the American viewpoint, where required. All 52 American delegates met in caucus each day, with Mr. Magdsick as Chairman, for a full discussion of the delegates' reports.

Three of the 23 papers given at the Congress were by American delegates. Considerable international interest was evident in the work described in these papers by Dr. H. R. Blackwell, Professor

(Continued on page 10A)

AT RIGHT, wing of splendid new Palais du Congrés, Brussels, site of the 1959 Congress of the Commission Internationale de l'Eclairage.

BELOW: Registration at the USA booth at CIE meeting. From right: Ben Hartmann, Art Barr, Willard Brown and Sylvester K. Guth.



TWO leading scientists in illumination discussing their theories at CIE. Left, H. C. Weston of Great Britain; behind desk at right, H. R. Blackwell, USA.

FROM the floor—lively discussion (here by C. L. Crouch, USA), with simultaneous translation in French, English and German, three official languages of CIE.

(Continued from page 9A)

P. F. O'Brien and Professor D. M. Finch, whose paper was co-authored by two delegates from Canada, John Chorlton and Hedley Davidson. The stature of American science in lighting in the world, and also the stature of its knowledgeable spokesmen, could well be a source of pride to lighting people in the U. S. Quite evidently, international respect is paid to work originating in this country, in several fields.

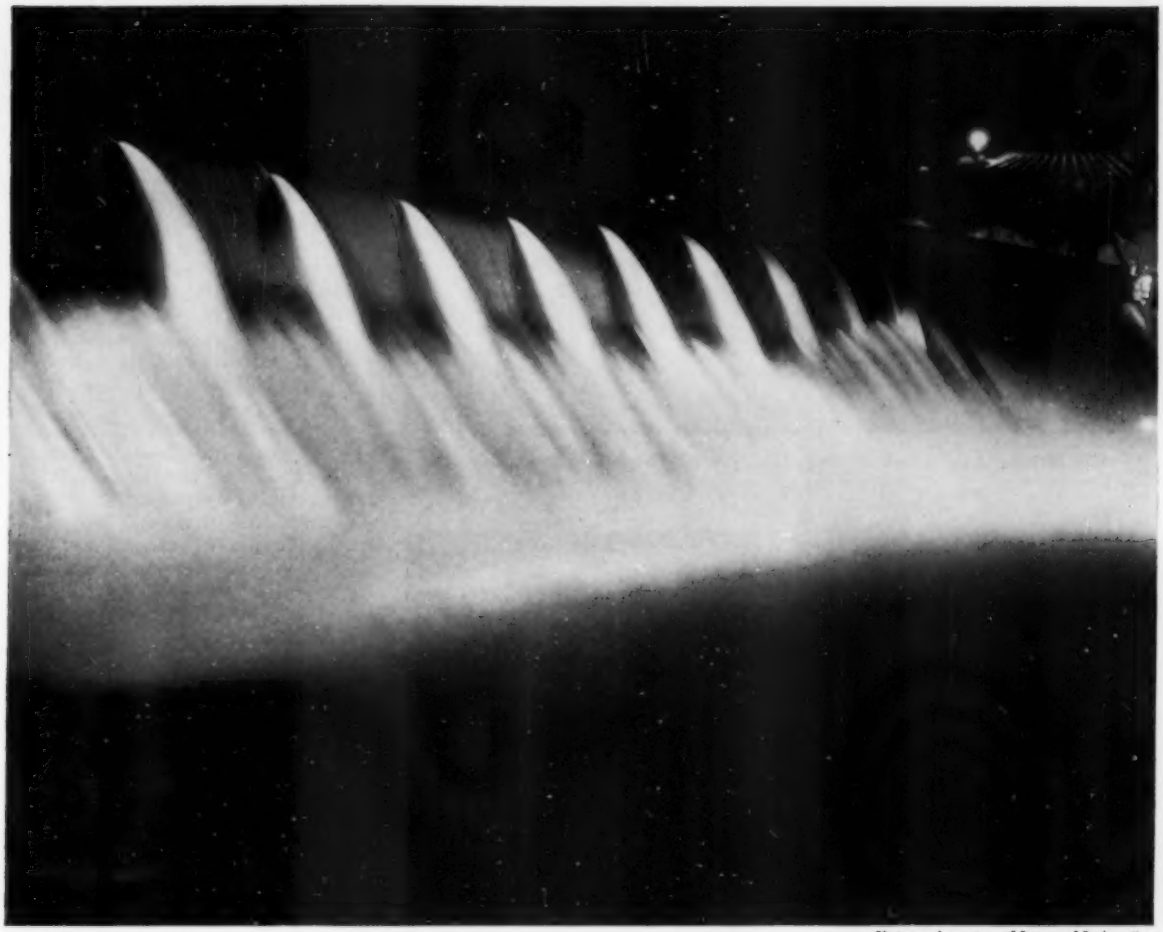
In addition to the formal program of Secretariat and Working Committee Sessions, the Belgian Committee of CIE, hosts to the Congress, had also arranged an extremely valuable series of "technical visits." These very efficiently conducted tours enabled visitors from all over the world to visit laboratories at Charleroi, Eindoven, Schreder and others, and to take extensive bus tours of street lighting, floodlighting and airport installations.

FROM the stage—American delegate Sylvester K. Guth expounds on comfort-discomfort studies.

Diversion and relaxation were provided by an excellent social program. Between technical meetings and over weekends delegates enjoyed a number of excursions. These included a trip by large ship up the River Shelt from Antwerp, with dinner aboard; bus excursion to Overijse, famed grape-growing area, where the group visited the acres and acres of greenhouses of Belgium's huge blue grapes and were guests of the mayor of Overijse for mid-afternoon refreshments of grapes, champagne and the country's good cheese; a Sunday trip to the Belgian Coast, including three hours at Bruges, with a wonderful Breughelian supper and dancing; a hike (almost 1000 people strong) through the Forest of Soignes. Evening entertainment included a candlelight Mozart concert; a reception with dancing at the beautiful 16th Century Brussels Town Hall; a theatre

(Continued on page 12A)

FEATURE of United States participation at CIE was daily Caucus of American delegates. Above, general view of caucus; at left, USNC officers, from left to right: Willard C. Brown, L. E. Barbrow, Herbert H. Magdsick (USNC President) and T. D. Wakefield.



Photograph courtesy of Bureau of Reclamation

PUTTING COLOR IN THE "FLOODS"

AT GRAND COULEE DAM

Here's your *problem*: Bathe the Grand Coulee Dam in a rainbow of colors. But keep in mind that *no fragile material will do* because there's *heat* from the high-powered floodlights, *cold* water spray, and the wearing effects of year-round *weather*.

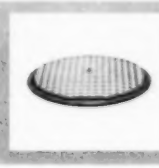
The solution? PYREX brand heat-resistant colored cover glasses from Corning, 686 in total. Each weighs 7 pounds and measures 18 inches across. There are reds, greens, yellows, and a *special* blue developed to produce white when added to red and green. This *special* blue was just another of Corning's many contributions to the lighting industry.

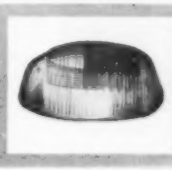
Suggestion: Whatever your lighting need—color correction, direction and control, protection, decoration—you're invited to make use of Corning research and production facilities.

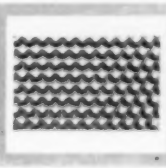
A note outlining your wants will bring a quick answer. Write to Corning Glass Works, 61 Crystal St., Corning, New York.

CORNING GLASS WORKS

CORNING MEANS RESEARCH IN GLASS







1. Airport runway marker 2. Traffic signal lens 3. Street light refractor 4. Pattern No. 70 Lens Panel for commercial applications. *You might find just what you're looking for in our standard line.*

CIE Delegates on delightful, mile-long stroll through Forest of Soignes.

(Continued from page 10A)

party at the Theatre Royal de la Monnaie; and a fabulous official banquet in the big Tapestry Hall of the Cinquantenaire Museum.

Great credit is due the Belgian committee responsible for this exceptionally successful international Congress. Especially to be congratulated, in addition to the entire Belgian CIE committee, are A. Boereboom, President of the Belgian Organizing Committee, and members of his committee: R. Montenez, R. Castadot, E. Clausset, J. Schreder, J. Hoffmann and Fr. Sarteel. In appreciation of their splendid work, some 150 delegates from all countries were in turn "hosts to their hosts" on the final day of the Congress, holding a dinner in their honor at the Circle Royale Gaulois Artistique in Brussels. Spokesman for the group was T. D. Wakefield, U. S. delegate, who conveyed (in French) the thanks and congratulations of the entire delegation.

BURGOMASTER'S Reception at Town Hall. At left, the Herman Lazersons; right, the Willard C. Browns.

ALSO on social program, Brueghelian supper at Wiese—*very* festive occasion!

New Officers Elected for CIE

At the final Plenary Session of the CIE Congress in Brussels on June 24, officers were elected to serve as Executive Committee for the coming four years. Elected as President of CIE was Ivar Folcker (Sweden), succeeding J. W. T. Walsh (Great Britain), who has served the group as President during the past four years.

Three Vice-Presidents have been re-elected to another four-year term: A. A. Brainerd (USA), R. Deaglia (Italy), and Hofrat L. Fink (Austria). A new Vice-President will be Prof. L. Schneider (Germany), succeeding M. Jacob (Belgium).

W. E. con Hemert of the Netherlands was re-elected as Treasurer, and Prof. Y. Le Grand (France) was also re-elected to another term as Secretary.

Other committee elections were: Finance Committee: Chairman, W. E. con Hemert (Netherlands); Members: R. Apestrand (Norway), J. G. Holmes (Great Britain), F. Krones (Austria), and A. Tchetchik (Israel). For the Papers Committee: Chairman, M. Cohu (France); Members: H. Korte (Germany), Russell C. Putnam (United States of America), J. M. Waldram (Great Britain).

These officers and committee personnel will serve until the next meeting of CIE, scheduled to take place in **Vienna**, Austria, in 1963.

ASTM Elects 1959-1960 Officers

Official announcement of the results of the American Society for Testing Materials' election of officers for 1959-1960 was made at the 62nd Annual Meeting of the Society, June 21-26, Atlantic City, N. J. Those elected include: President—F. L. LaQue, International Nickel Co.; Vice-President—Miles N. Clair, Thompson & Lichtner Co.; three-year terms on Board of Directors—A. B. Cornthwaite, Department of Highways, Commonwealth of Virginia; C. L. Kent, Jones & Laughlin Steel Corp.; H. C. Miller, Public Service Electric and Gas Co. (N. J.); C. E. Nixon, General Motors Corp.; H. D. Wilde, Humble Oil & Refining Co., and I. V. Williams, Bell Telephone Laboratories.

In accordance with a change in the Society's by-laws, Robert D. Thompson, Taylor Instrument Co., was elected to a two-year term on the Board of Directors. A. Allan Bates, Portland Cement Association, continues in his two-year term as Vice-President.

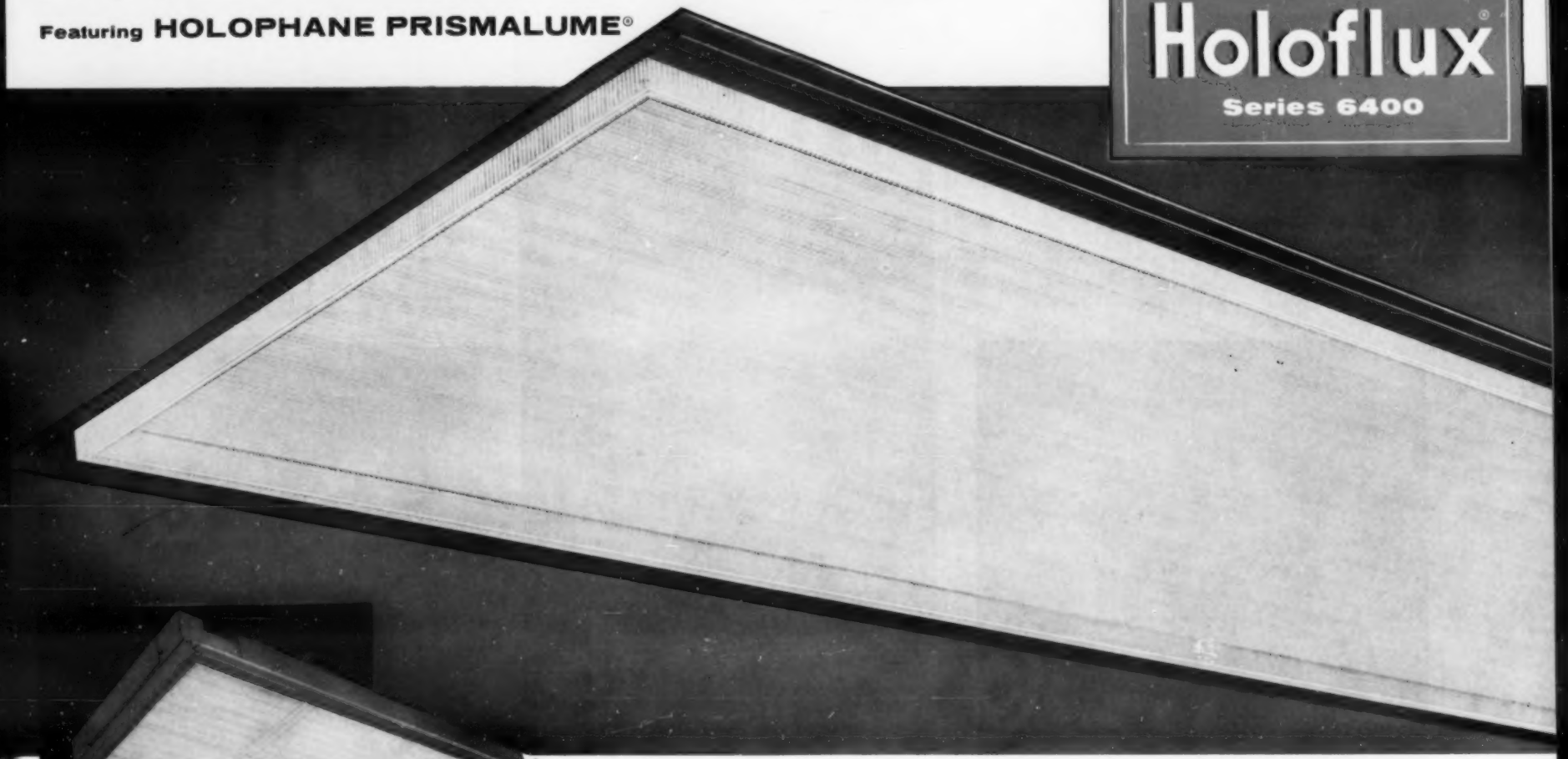
(News continued on page 15A)

TOTALLY NEW!...Recessed 2-Foot Wide Luminaires...

Featuring HOLOPHANE PRISMALUME®

Holoflux®

Series 6400



In Two Lens Designs...

Nos. 6400-6410: with Prismatic Border for ceiling illumination *(upper)*

Nos. 6420-6430: with Flat CONTROLENS® for unbroken ceiling lines *(lower)*

Basic units are made in 4-foot lengths (2, 3 or 4 rapid start lamps per section)... Distinctive design integrates with contemporary interiors... stores, offices, terminals, showrooms, banks, drafting rooms, schools and other institutional buildings.

The Only Luminaires Made with ALL these Advantages!

(1): Highest utilization of light; minimum brightness and glare... (2): PRISMALUME (crystal acrylic plastic) for extra-durable service; no discoloration... (3): Supporting cross-members do not project above top of recessed portion of luminaire... (4): Easy adjustment on irregular ceilings or in alteration work... (5): Great versatility; models for major, commercially available, ceiling types... (6): Completely designed and produced by HOLOPHANE — with over six decades of experience devoted exclusively to lighting.

Write for Engineering Data

Holophane

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Lighting Authorities Since 1898

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THE HOLOPHANE CO., LTD., 419 KIPLING AVE., CO., TORONTO 18, ONT.

Here and There With IES Members

Special invitations went to Sustaining Members, utilities and distributors in the area for Puget Sound Section's luncheon meeting with National President G. J. Taylor. Shown here at the head table are: Seated, l. to r., B. A. Travis, Pacific Northwest Regional V-P; President Taylor; R. E. Jones, Section Chairman. Standing: F. C. Scharr, Sustaining Membership Chairman and Sustaining Members A. C. Tyler, Seattle City Light Co.; R. F. Plymire, Puget Sound Power & Light.

Sustaining Members' Night at Southern California Section's last meeting of 1958-1959 year. Some of the IES supporters shown here with Roy Dahlin (left), Section's Sustaining Membership Chairman, are, in the usual order: L. C. Witt, City of Glendale, Public Service Department; G. R. Thedaker, City of Burbank, Public Service Department; Ted Shepherd, City of Los Angeles, Department of Water & Power; (B. J. Hartmann, Section Vice-Chairman); Ed Balogh, Sunbeam Lighting Co., Gene Wade, Acme Lighting and Mfg. Co.; Clem Smoot, Smoot-Holman Co.

Program highlight of the Southern California meeting honoring Sustaining Members (above) was MMILJ competition by, left to right, Mel Paul, first prize; Norman Tyler, third prize; Jack Gates; Charles Conn; Bill Weist, second prize and Bill Reed.

Representing the Sections and Chapters of the Pacific Northwest Region were, left to right: Fred Dorward, Edmonton; Graham Foster, British Columbia; Regional V-P Beverly Travis; William Warrack, Chinook; R. C. B. Jarvis, Edmonton; R. E. Jones, Puget Sound; President George Taylor; T. W. Beadle, Inland Empire Chapter; Jack Cottingham, Oregon Section.

Canadian Rockies—Site for Pacific Northwest Regional Conference

One aspect, often commented upon, about IES meetings and regional conferences is the warm friendly spirit of those attending. This seemed particularly true of the Pacific Northwest Regional Conference, held at the Banff Springs Hotel, in Banff, Alberta, May 26-29. Perhaps it was the spectacular beauty of the setting, the towering Canadian Rockies, which inspired the feeling of camaraderie which pervaded the meeting. Whatever the cause, delegates and guests found the conference, co-sponsored by Edmonton and Chinook Chapters, a real success.

One happy event, made possible by a special action of Council, was the chartering of the Edmonton group as a Section. Although, strictly according to the rules, the Chapter did not come of age unil June 14, Council's action permitted the charter presentation at the conference by IES President George Taylor. Fred Dorwood, Edmonton Chairman, accepted the charter for the new Section.

The Chinook Chapter, the other co-host, was also honored at a ceremony, when Regional Vice-President Beverly Travis presented a membership plaque to Chapter Chairman Bob Shortreed for the year's record meeting attendance of 71 per cent.

The two Canadian groups, in return, gave gifts to President Taylor, Mrs. Taylor and Mrs. Travis. Mr. Taylor was presented with "A Share in Alberta" in the form of 300 oil shares—something which will surely remind him of his visit to Banff. Mrs. Taylor and Mrs. Travis received gifts of inlaid bowls with a western motif.

The MMILJ contest was, as is usual, a highlight of the conference, with James E. Beck of the Oregon Section winning in Class I, for residential lighting. Class II winners were: first, Fred A. Farley, Oregon Section, with a luminous ceiling installation in a bank; second, D. E. Frank, Inland Empire Chapter, for lighting the Turf Room and Country Restaurant; honorable mention, Karl Haselsteiner, British Columbia Section, for the lighting of the New Deas Tunnel.

One unusual, interesting and entertaining item on the program, which was received wtih great enthusiasm, was a floodlighting demonstration, presented by Don Frost, of Calgary, substituting for W. A. Dalrymple, of Toronto. In the demonstration the warm tones of sodium light intermingled with the cooler colors of mercury.

For the ladies, in addition to the demonstration, dinner dance, cocktail parties, and luncheons, there were teas, tours, golf, swimming, bridge and an outdoor putting contest.

Credit for the conference goes to R. C. B. Jarvis of Edmonton and Don Frost of Calgary, and to the following committee chairmen:

Budget and Finance—A. T. Robertson, Edmonton, and M. Luft, Calgary
Entertainment—A. Longmate, Calgary
Hotel—L. McKenzie, Calgary
Papers and Program—J. M. Connauton, Edmonton, and R. Shortreed, Calgary
Properties and Audio-Visual Aids—R. Mason, Calgary
Publicity—D. Little, Calgary, P. King, Edmonton, and D. Tucker, Edmonton
Reception-Registration—T. A. Tame, Calgary, and E. Johnson, Edmonton
Transportation—Russ Smith, Calgary
MMILJ Contest—J. Morgan, Edmonton
Ladies' Committee—Mrs. R. C. B. Jarvis, Edmonton

PROGRAM

May 27 — Morning

Call to order and introductions—R. C. B. Jarvis and Don Frost, Conference Co-Chairmen
Address—J. Carl Wilson, Canadian Regional Vice-President, and Beverly Travis, Pacific Northwest Regional Vice-President
Address—G. J. Taylor, IES President
Chairman—Graham Foster, British Columbia Section
Lighting Concepts Today and Tomorrow — E. A. Linsday, General Electric Co., Cleveland, Ohio

May 27 — Afternoon

Chairman—T. W. Beadle, Chairman, Inland Empire Chapter
Hazards and Pitfalls in Footcandle Calculations—R. E. Jones, Sunbeam Lighting Co., Seattle, Wash.

(*Continued on page* 18A)

Membership attendance plaque awarded to the Chinook Chapter is received by Chairman Bob Shortreed. Regional V-P Beverly Travis, left, makes the presentation.

Gift to President Taylor—"A Share in Alberta"—300 shares of oil stock presented by Don Frost, left, and R. C. B. Jarvis, right, conference co-chairmen.

from **RAW MATERIAL**.....

PAINSTAKING

GUARANTEES THE **LIGHT**—THE **LAMP LIFE**.....

NO OTHER BALLAST MANUFACTURER conducts the comprehensive and uncompromising quality control procedures that *every* Jefferson ballast must undergo before it can be shipped.

This extra care PAYS OFF FOR YOU . . . by assuring you a ballast that will obtain the full rated light output from the lamp it activates—a ballast that will *protect* rather than diminish the life of that lamp by guarding against pre-ignition, end blackening, etc. And, of course, the ballast itself will last *much* longer—slashing your maintenance and replacement costs.

For example: Almost all ballast manufacturers test the electrical characteristics of the silicon steel that goes into the core—JEFFERSON goes beyond the ordinary

Silicon steel has been cut to core-size and shape laminations and is here undergoing electrical tests, such as core loss, permeability, etc.

Core-coil test board on production line determines adherence to electrical requirements in sub-assembly.

Jefferson

.....thru **FINISHED PRODUCT**

QUALITY CONTROL

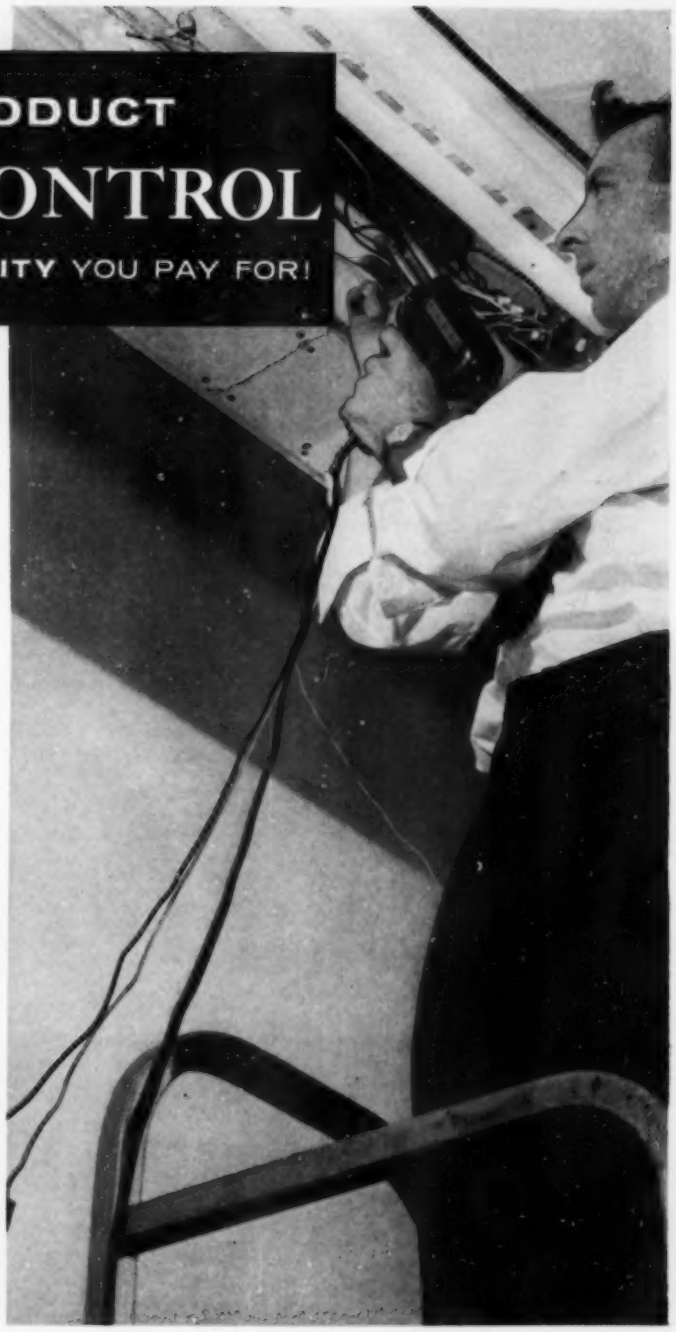
.....THE **BALLAST DEPENDABILITY** YOU PAY FOR!

tests and cuts that steel into core-size and core-shape laminations before testing. Result: JEFFERSON knows with precise accuracy the characteristics of the steel in its ballasts—so JEFFERSON ballasts operate more closely to the exact requirements of the lamps they regulate—thereby protecting—and prolonging the life of these lamps.

Most manufacturers "spot check" their ballasts in final assembly form—JEFFERSON final tests EVERY ballast off the line. RESULT: you can count on Jefferson dependability.

There's more—MUCH MORE to the Jefferson quality control story—ask your Jefferson representative.

Condensers, like all "purchased parts" that go into a Jefferson ballast, are thoroughly tested upon reception.



How will the ballast perform in your fixture? Ballast here is being installed in fixture as a practical simulated field test for heat rise.

FLUORESCENT BALLASTS

JEFFERSON ELECTRIC COMPANY • BELLWOOD, ILLINOIS

Charter of Section status is presented to Edmonton Chairman Fred Dorward by IES National President George Taylor. Presentation at the conference was made possible by a special action of the IES Council.

MMILJ winners receiving certificates. Left to right: President George Taylor; J. E. Beck, Oregon Section, first prize in Class I; Jack Cottingham, proxying for first prize winner in Class II, F. M. Farley, Oregon Section; Don Frank, Inland Empire Chapter, second prize in Class II; Ernie Kingsley accepting honorable mention for Carl Haselsteiner.

(Continued from page 15A)

MMILJ Contest
"No Host" Cocktail Party
Dinner

May 27 — Evening

Chairman — Tom Mawson, Vancouver Island Chapter
Floodlighting Demonstration — Don Frost, Amalgamated Electric Corp., Calgary, Alta.

May 28 — Morning

Chairman — R. E. Jones, Chairman, Puget Sound Section
Stage Lighting and Its Various Aspects — Ariel R. Davis, Ariel Davis Manufacturing Co., Salt Lake City, Utah
Highlights of Commercial Lighting—George Taylor, Day-Brite Lighting, Inc., New York, N. Y.
Planned Street Lighting—George Cornish, City of Calgary, and Frank Wilson, City of Edmonton
President's Luncheon—President's Message by George J. Taylor

May 28 — Afternoon and Evening

Tours, Golf, Swimming, Bridge
Reception and Cocktails
Buffet Dinner and Party
Dancing

May 29 — Morning

Chairman—Jack Cottingham, Oregon Section
The Application of Fluorescent and Mercury Lamp Ballasts—George I. Campbell, Canadian General Electric Co., Toronto, Ont.
Progress Report, "Reaching for the Sun"—E. A. Linsday, General Electric Co., Cleveland, Ohio
Luncheon

Edmonton Section delegates, l. to r. kneeling: Frank Wilson, R. McNeil, Art Baragon, Dennis Tucker; standing: Don Shannon, Ron Vernon, Ray Carmichael, Jack Connauton, Reg Jarvis, Johnny Morgan, Roger Young and E. M. Johnson.

International Recommendations Proposed at CIE Congress

All of the results of the work transacted and the papers presented at the Congress of the International Commission on Illumination (Brussels, June 15-24, 1959) will in due time be presented, together with discussion, in the official CIE *Proceedings*. This is expected to be available early in 1960.

Meanwhile, however, comment is invited on the technical recommendations tentatively adopted. Although these recommendations are only tentatively approved, they will become effective within six months unless objection is entered by any National Committee. Anyone wishing to comment on, or object to any of these Recommendations should communicate at once with L. E. Barbrow, Secretary of the United States National Committee. His address is: National Bureau of Standards, Washington 25, D. C. The limiting date for comments or objections is October 1, 1959. A limited number of copies of this document which includes the Recommendations, list of papers and technical committee reports are available from Mr. Barbrow.

Recommendations tentatively adopted cover such subjects as:

Committee S-1.2. — Measurement of Light
Committee E-1.3.1.—Colorimetry
Committee S-1.4.1.—Photopic and Scotopic Vision
Committee S-2.1.1.—Sources of Visible Radiation
Committee S-3.1.5.—Mine Lighting
Committee S-3.3.2.2. — Lighting for Transport Other Than Automobile and Air.

(News continued on page 20A)

Why Lustrex Perma Tone Styrene for ceilings?

3 times more resistance to yellowing that's why! Perma tone was specially developed to meet IES-NEMA-SPI joint specifications for ultra violet light stabilized styrene—exceeds the requirements of these specifications. ▪ Truly translucent whites and a wide range of colors. ▪ Uniform light distribution characteristics. ▪ Large areas of illumination, good diffusion. ▪ Light weight for easy handling, installation, and maintenance. ▪ Dimensionally stable. ▪ Low cost.

FOR FREE TECHNICAL REPORT on Lustrex perma tone styrene, including accelerated test results and other valuable data on styrene in lighting fixtures, write to Monsanto Chemical Company, Plastics Division, Room 1318, Springfield 2, Mass.

Monsanto

LUSTREX: REG. U.S. PAT. OFF. ®

GRATELITE Louver-Diffuser by Edwin F. Guth Company, St. Louis, in conference room of the American Dental Association, Chicago, Illinois. Molded of Lustrex perma tone styrene by Koller-Craft Plastics Products, Inc., Fenton, Missouri. Architect and Engineer: Childs & Smith; Contractor: White City Electric Company; Distributor: Graybar Electric Company.

SPEAKERS at the Friday morning session, l. to r.: front row, John Neidhart, President George Taylor and Leo Duval, Jr.; back row, E. A. Linsday, Willard Allphin, and Jack Hamilton, Chairman of the New York Section, who presided at the session.

SOME of the MMILJ contestants in Class II, l. to r.: front row, Russell Benjamin, Connecticut; Meyer Silverman, New Jersey; back row, Randall Rice, Eastern New York; R. G. Williams, New York, first in the Region; Warner Helston, New Jersey and Ray Warner, Yankee Section.

Yankee Section Host to Northeastern Regional Conference

Still another IES Chapter achieved Section-hood while acting as host to its regional conference. This was the Yankee Section, whose Section Charter was presented at the Northeastern Regional, held in the heart of the Berkshire hills, at the Curtis Hotel, Lenox, Mass., June 4 and 5.

Attendance was 134, as the table of statistics shows, with visitors from three out-of-Region Sections. Following registration, the two-day meeting was opened by C. J. Forster, Chairman of the Conference, who welcomed the delegates and guests. Yankee Chairman Bart Barry then introduced the speakers: John Downing, Executive Director of the Berkshire Hills Conference; George Taylor, IES President; and Raymond Smart, Northeastern Regional Vice-President.

Technical Program

The technical program began with E. A. Linsday, General Electric Co., who presented the heralded Progress Report. Fred Wolfe, of Sylvania, whose subject was electroluminescence and the part it plays in auto panels and electric appliances, spoke next. Murray Quin, Day Brite Lighting Inc., then discussed Lighting and Air-Conditioning through Combination Fixtures. Dana Rowten, Westinghouse, wound up the session with a discussion of Street Lighting — New Sources and Optical Systems.

The afternoon session was conducted by Richard Smith, Chairman of the New England Section, and the first speaker was W. S. Till, of Westinghouse Electric Co., who spoke on Improved Performance in Color and Quality of Mercury Lamps. R. A. McCarthy, of the Monsanto Co., then discussed Plastics in Lighting. Following a coffee break, the eight contestants in the My Most Interesting Lighting Job (three in residential and five in commercial) put on their demonstrations.

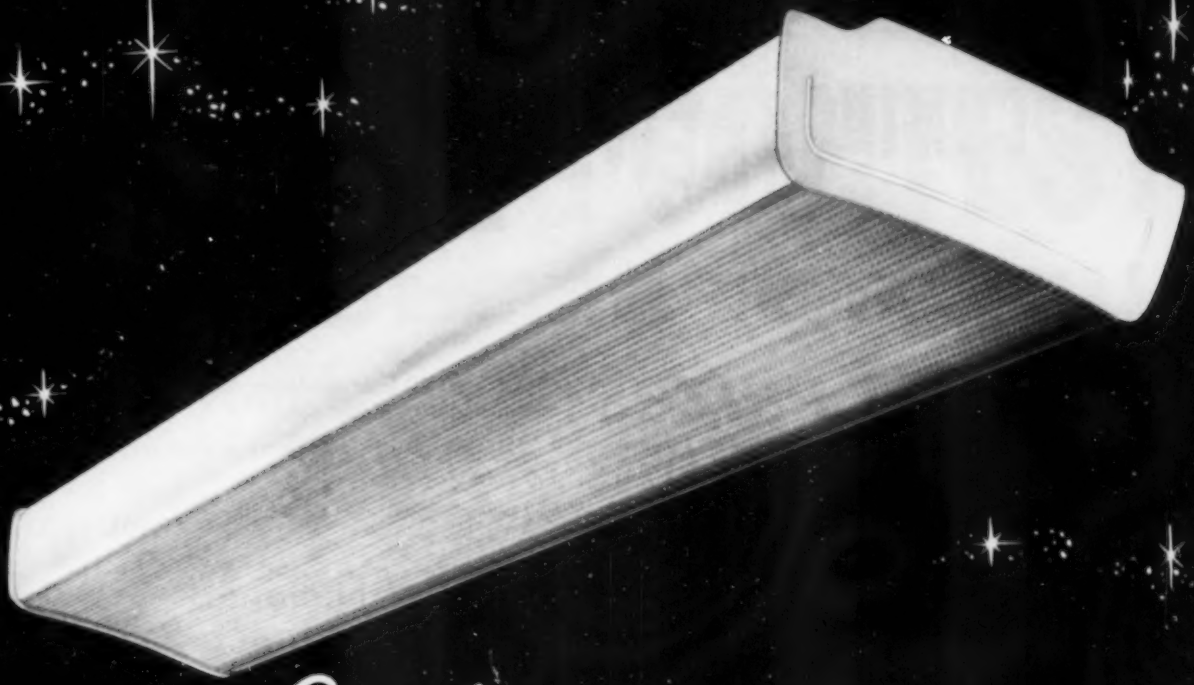
The Friday morning session was chaired by John Hamilton, New York Section Chairman. It opened with a History of the 1959 Handbook, by John Neidhart, The Miller Co., who was chairman of the Handbook Committee. Leo Duval, Jr., of Sylvania, then presented An Economic Study of an Industrial

(Continued on page 25A)

Attendance Statistics

Northeastern Region	
Connecticut Section	25
Eastern New York Section	12
New England Section	37
New Jersey Section	13
New York Section	12
Yankee Section	27
Out-of-Region	
Chicago Section	2
Cleveland Section	3
St. Louis Section	1
Members registered	132
Unassigned guests	2
Total registered	134
Wives registered	36

PLEASED and proud, President and Mrs. Taylor hold their painting, a gift from the Region. Left to right are: Mrs. Ray Smart, President Taylor, Cliff Forster, Art Brodeur, Jr., Mrs. Taylor and Ray Smart.



PREMIUM *Quality* IN THE GARCY TRADITION

AVAILABLE NOW AT A LOW-BUDGET *Price*

The New *Gar-Lite* 101 by GARCY LIGHTING

Exclusive one-piece shield combines two tones, does two jobs

Diffuse white sides prevent objectionable side brightness

Clear prismatic bottom offers controlled high efficiency

Shield hangs down from either side on continuous hinge

Two-lamp unit (illustrated) is less than 9″ wide, 3¼″ deep

Exact 48″ length; joins end to end quickly and easily

Write for Bulletin 59

AVAILABLE THROUGH SELECTED GAR-LITE DISTRIBUTORS

GARCY LIGHTING

DIV. OF GARDEN CITY PLATING & MFG. CO.
2475 ELSTON • CHICAGO 47, ILLINOIS

COMING NEW $100,000 STOPS and SELLS

4 FIRST PRIZES

PLUS 1,004 OTHER PRIZES

each a $20,000 Light-for-Living Medallion Home—constructed on winners' lots.

4-$1500 groups of electric kitchen appliances

500 portable lamps

500 packages assorted light bulbs

National Contest Announcements

LIFE

LOOK

The Saturday Evening POST

Reaching **81,950,000** HOMEMAKERS *plus* **4 MILLION MORE**

a **spectacular** bonus from Life's 30-page Medallion Home Section in their September 14 issue.

Hundreds of thousands of homemakers in your shopping area are being told to "get their official contest entry booklet at their favorite store selling lamps, fixtures and bulbs."

They'll all want to win this contest—they must come to you for contest entry forms. Make sure you're ready to turn these requests into sales and profits!

LIGHTING CONTEST

CUSTOMERS FOR YOU!

Make your store Contest Headquarters

Use these tie-in contest materials

Official contest entry booklet . . . contains contest rules, official entry form and complete educational information, selling your customers on Light-for-Living. This booklet is available to consumers *only through local outlets*—which means YOU!

Colorful window streamer (30" x 14") . . . will bring customers through your doors and past your merchandise for contest entry booklets.

Eyecatching door or window decals . . . to identify your store as contest headquarters—a real stopper-shopper idea! . . . and puts you at the payoff point of the Light-for-Living national promotion all year!

Newspaper ad mats and glossies . . . use these in your own ads to promote this national contest as your own local contest.

Radio and TV scripts . . . just add your name, as Contest Headquarters, to these exciting sales messages.

Use this decal

LIGHT FOR LIVING
HEADQUARTERS

IDENTIFY YOUR STORE AS HEADQUARTERS FOR THIS NATIONAL CONTEST

Here's how:

- **Contact your local electric utility company today . . .**
- **They will help you with all of the contest materials you need to tie-in.**

Be ready:

- **Homemakers in your area will want to WIN this big, nationally-advertised contest . . .**

Customers are being told to come to YOU:

- **Customers MUST come to you for official contest entry booklets.**
- **Everything they need to win is included in this booklet.**
- **This contest booklet is available ONLY at local lighting outlets—YOUR STORE!**

* * *

This is the kind of traffic-building promotion you've been waiting for. Imagine how it will boost sales of lamps, fixtures and bulbs and increase profits for you!

In addition, many local Electric Light & Power Companies are sponsoring models of the prize-winning Light-for-Living Medallion Homes for customers' inspection in your area.

This is the first industry-wide, national-residential lighting program. And it's part of the multi-million dollar National Electric Living Program.

Cash in on this tremendous promotion through your local Electric Utility Company.

LIVE BETTER ELECTRICALLY

LIVE BETTER . . . ELECTRICALLY

sponsored by Edison Electric Institute

THIS IS THE FAIRVIEW

New 8-foot lighting value by Day-Brite.
With one-piece, metal-framed enclosure of X-5 plastic.
Exclusive CLEARTEX® panel for low brightness.
Upswept sides for soft gradation of light on ceiling.
Separable hinges for one-man servicing.
Clean, crisp design complements any interior.

FAIRVIEW offers all the visual comfort, quality features, and ease of installation and maintenance you expect from Day-Brite . . . at about half the price you'd expect to pay!

Applications include schools, offices and stores. Surface or suspension mounting. Available for 8-foot Slimline or 4-foot Rapid-Start lamps. For more information on FAIRVIEW, call your Day-Brite representative listed in the Yellow Pages. Or write Day-Brite in St. Louis. Day-Brite Lighting, Inc., 6260 N. Broadway, St. Louis 15, Mo.; 530 Martin Ave., Santa Clara, Calif.

CHARTER of Section Status is presented by President Taylor to Yankee Chairman Bart Barry. Mrs. Taylor and Regional V-P Ray Smart are at right.

POOL-SIDE diversion—fashion show for the ladies included modeling of bathing suit by Curtis Hotel hostess, Mrs. Rita Payson.

(Continued from page 20A)

Area. E. A. Linsday, G-E, gave Views on the New Footcandle Levels, as did Willard Allphin of Sylvania. This was followed by an unscheduled panel discussion by Mr. Linsday, Mr. Allphin and President Taylor, resulting in lively discussion from the floor.

The afternoon session was conducted by Harold Young, Connecticut Section Chairman, who introduced Miss Kathleen Downey, Western Massachusetts Electric Co., who spoke on Lighting Homes and Gardens. The next speaker was Willard W. Thompson, of Thompson Engineering, whose topic was Cooperation Between Architect and Lighting Engineer. Final speaker in the technical program was R. A. Langer, Kleigl Brothers, who discussed Dimming Fluorescent and Incandescent Lamps. Regional V-P Ray Smart made the closing remarks.

Entertainment

The President's Reception, Banquet and Ball, as ever, was the high spot of the social program, and the occasion for the presentation of a gift to Mr. and Mrs. Taylor. This was a painting of a typical New England landscape. Presentation of the new Yankee Section Charter was also made at this time.

Also at the President's Dinner were the awards to the winners of the My Most Interesting Lighting Job Contest. These were Sylvan R. Shemitz, first in Class I, Connecticut Section, New Haven Electric Supply Co., West Haven, Conn., for his entry on Lighting for Relaxation; in Class II, R. G. Williams, Century Lighting Inc., New York Section, won top honors with his installation at the Toronto Royal Hotel.

Other events planned to entertain the ladies were a "Get Acquainted Coffee Hour," ping-pong and shuffleboard, swimming in the hotel's heated pool, a fashion show and an exhibition by the Aquacade Swimmers. Tours by bus were arranged, to places of local interest.

Credits

General Conference Chairman—Clifford Forster
General Conference Treasurer—Charles Morse
General Conference Secretary—Charles Gansis
Papers—Francis Conlin
Publicity—Frank Hayden
Hotel and Transportation—John K. French
Ladies' Program—Mrs. Barbara Barry
Budget—Gordon Foot
Entertainment—Arthur Brodeur
Lighting Display and Decoration — Alden Rhodes
Program—Dr. D. R. Provencher
Photographs—J. Brusig, K. Haswell and Ray Warner

IES Gold Medal Presented During CIE Brussels Meeting

Dr. N. A. Halbertsma, 1959 Gold Medalist, was presented with this award at the Palais du Congrés in Brussels on June 15. (See May IE, page 5A for details of award.) The impressive award ceremony was attended by the entire American delegation at the CIE Congress, as well as by numerous other friends of Dr. Halbertsma. Presentation of the Medal and Certificate was by Professor E. M. Strong, with an introduction by Herbert H. Magdsick, President of the United States National Committee of CIE.

Although Dr. Halbertsma, whose home is in Holland, will not be present at the IES National Technical Conference in San Francisco this September, further ceremonies will be held during the Con-

(Continued on page 28A)

DR. N. A. HALBERTSMA of the Netherlands (right) accepts IES Gold Medal and Certificate of Award from Professor E. M. Strong. This top IES honor was presented to Dr. Halbertsma in Brussels on June 15, between sessions of the CIE Congress there. Introduction was by H. H. Magdsick (not shown), President of the United States National Committee of CIE.

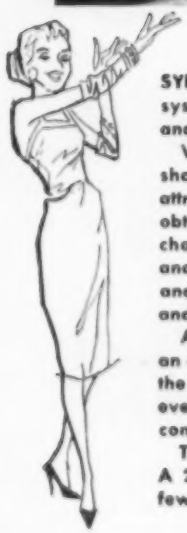
Choose from 3 *distinct and different*

Area Lighting Systems . .

Before you specify lighting again, take another look at the decided advantages of Area Illumination. See how it can add to and help your overall planning.

As a design element, today's completely or partially-luminous ceilings offer possibilities limited only by the designer's aims. Area Lighting can make the ceiling surface an integral part of your entire scheme, both esthetically and in space planning through partition coordination.

From a lighting viewpoint Area Lighting stands alone. No other present-day lighting method provides such comfortable, shadow-free and glare-free illumination regardless of lighting level.



SYLVA-LUME—This extremely versatile, modular system features an extruded aluminum grid work and offers unlimited flexibility and design freedom.

Vinyl plastic panels are provided in deep or shallow style—plain or patterned—in a choice of attractive colors. Single or double panels can be obtained. Optional acoustic baffles, also with a choice of colors, provide effective sound control and add another design element for delineation and emphasis. Perimeter panels give interesting and attractive border treatment.

All of these design factors can be utilized for an endless variety of ceiling patterns . . . allowing the addition of a distinctive personal touch to every installation from a relatively few catalogued components.

The standard Sylva-Lume module is 3' x 3'. A 2' x 2' module is also available with only a few limitations in variety.

SYLVA-CELL—This Sylvania modular system utilizes a 2' x 4' module and features a continuous pattern of cells. A choice of two attractive louvers is offered—polystyrene plastic or white painted aluminum, both with 45° x 45° shielding. Each ceiling offers excellent efficiency and shielding together with an even, widespread distribution of diffused illumination.

Sylva-Cell's simple, inverted-T grid work of extruded aluminum has extreme versatility for complete or partially-luminous ceilings. The louvered pattern can be used from wall to wall. Or, if desired, the interspersing of standard opaque ceiling materials makes a change in appearance, yet uses the same suspension system.

With Sylvania's minimum number of precision-made parts, installation is simple and fast. The open pattern of cells results in extremely minor problems of maintenance.

Go modern...with a Sylvania Lighting System!

.. by SYLVANIA

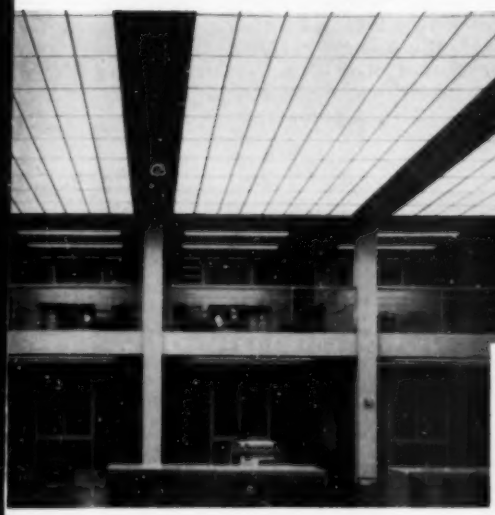
At Sylvania continual progress has been made in Area Illumination since providing the first catalogued lighting system over ten years ago. As shown below, Sylvania now offers 3 distinct and different Area Lighting Systems. All 3 systems use standard components and each one provides top-quality, efficient illumination together with smooth, uncluttered appearance.

These systems have been developed and perfected to give the designer almost unlimited freedom of expression. Color and patterns can now provide exciting vitality to routine ceiling areas.

Unique, specially-designed parts allow Sylvania Systems to be installed quickly and easily, reducing installation time and costs, and widening the application possibilities of Area Lighting in both new and modernization projects.

The next time, when you want lighting that is truly outstanding, look to Area Illumination . . . and think first of Sylvania where you have a choice of three Area Lighting Systems.

SYLVANIA LIGHTING PRODUCTS
A Division of SYLVANIA ELECTRIC PRODUCTS INC.
Department 59-7
One 48th Street, Wheeling, West Virginia



SYLVAN-AIRE—Sylvania's established area lighting system, featuring 3' wide rows of corrugated vinyl plastic, offers a most economical method of obtaining area illumination.

Sylvan-Aire offers two versatile suspension methods . . . Uni-Space and Vari-Space . . . making installation simple for any desired footcandle level. This system is easily adjusted for installation of air conditioning components, for spotlights, to fit around columns and other obstructions, or for partition planning.

Acoustic baffles are available, too, as optional equipment. When ordered, acoustic baffles are supplied pre-assembled to the support channels thus requiring no additional installation time.

SYLVANIA
Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

FLUORESCENT LIGHTING FIXTURES AND SYSTEMS • BEST FIXTURE VALUE IN EVERY PRICE RANGE

(Continued from page 25A)

ference in connection with this top honor of the Society. Dr. Halbertsma's address, following presentation of the Medal in Brussels, will also be read at the opening session of the San Francisco meeting.

To further fete Dr. and Mrs. Halbertsma, Herbert H. Magdsick was host to a formal dinner party in their honor at the Amigo Hotel in Brussels on the evening of June 15. This was attended by a number of American and Netherlands delegates: Mr. and Mrs. J. Jannssen of Eindhoven; Dr. and Mrs. Ward Harrison; Professor and Mrs. Everett M. Strong; Mr. and Mrs. Willard C. Brown; Mr. and Mrs. S. G. Hibben; Mr. and Mrs. C. A. B. Halvorson (last year's Medalist); Mr. L. E. Barbrow and Miss Ruby Redford.

ANNIVERSARY TABLE of Chairmen at meeting celebrating the Atlanta Residence Lighting Forum's tenth year. Left to right: Nina Faye Bonner, 1952-1953; Fern Moran, 1951-1952; Emily Alexander, 1950-1951; Ruth Morris, 1949-1950 and 1959-1960; Taylor Peake, 1958-1959; Rita Kuzell, 1957-1958; Jack Burns, 1956-1957; Elizabeth Parker, 1955-1956 and Mary Bush, 1954-1955. Unavoidably absent was Judd Lough, 1953-1954. Celebration was at joint meeting of Forum and Georgia Section.

Atlanta Residence Forum Celebrates Tenth Anniversary

Combination technical program and party at a joint meeting of the Atlanta Residence Lighting Forum and the Georgia Section of IES marked the tenth anniversary of the founding of the Forum, the Society's fourth. On the technical side was James Jensen, General Electric Co., Nela Park, with an informative talk on structural lighting in homes. A special anniversary table of present and past (except one) Forum Chairmen highlighted the celebration.

The Atlanta Forum began in May 1949 with 44 members, and the total at the start of 1950 was 71. Present membership is 102 of which 46 are associates (members of IES and the Forum) and 57 are affiliates (Forum members only).

Ruth Morris, first Chairman of the group, has been elected to lead the Forum again—in its eleventh year. Other officers are: Lois Goeke, Secretary; W. T. Cantrell, Treasurer; Grace T. Marsh, R. J. Kuzell, Nell Collins, and V. H. Branham, Members-at-Large.

Members and guests in attendance at the meeting numbered over 70.

ANOTHER Chapter is added to IES roster as Canadian Regional Vice-President, J. Carl Wilson, (foreground) presents Charter to Executive Board of Golden West Chapter, l. to r.: W. H. Hems, Secretary-Treasurer; Lorne Ritenburg, Chairman; Bart Howard, John Campbell and Richard McDonald, Board of Managers. Seated is Allan Burnard, Chairman of sponsoring Winnipeg Chapter.

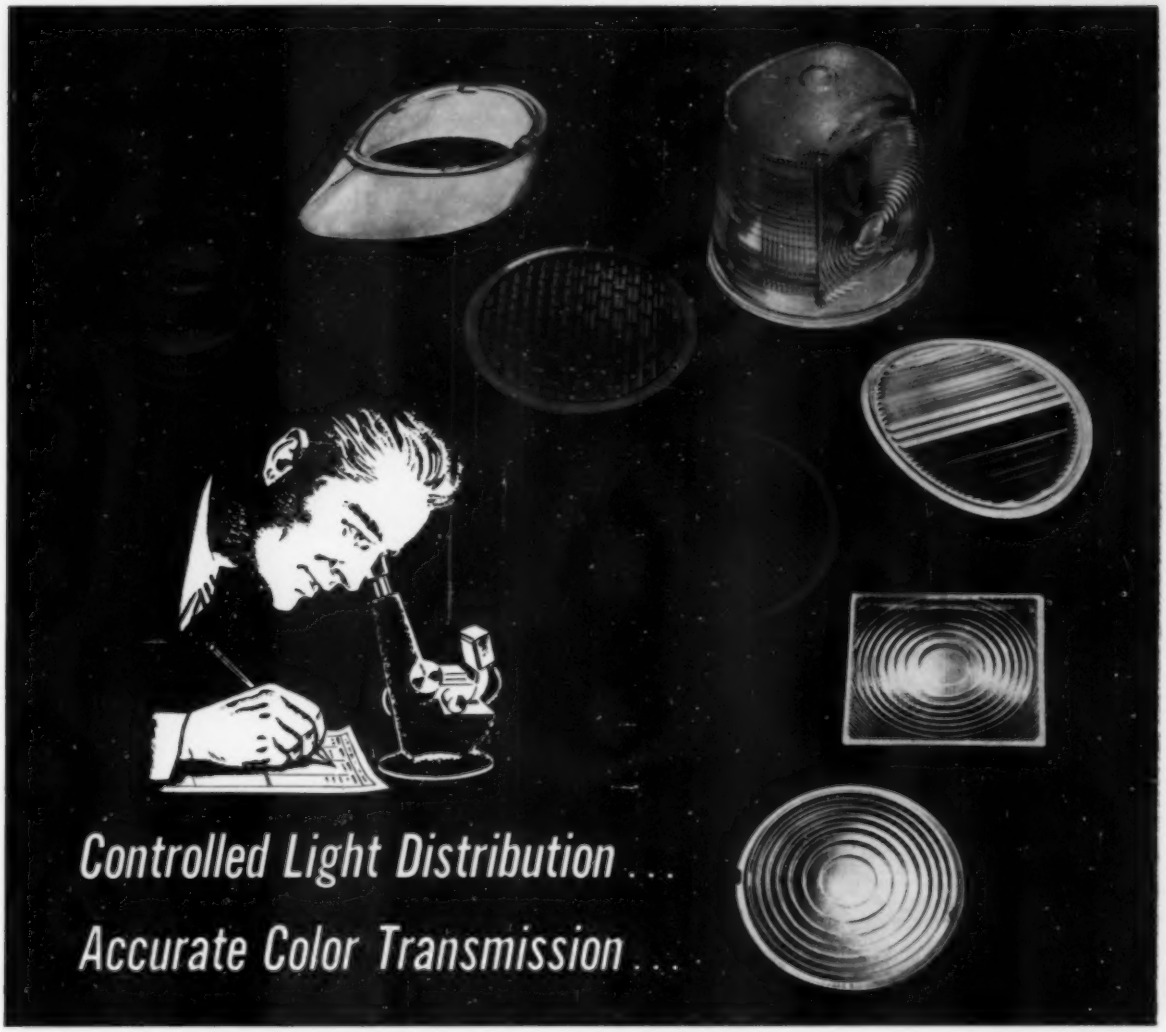
Golden West Chapter Newest IES Group

With local dignitaries and IES'ers from the neighboring Winnipeg and Edmonton Chapters in attendance, Canadian Regional Vice-President, J. Carl Wilson, officially chartered the Society's newest—Golden West Chapter. The addition of this group, headquartered in Regina, Sask., brings the number of active IES Sections and Chapters to 87.

Installation of Golden West's first officers — Lorne Ritenburg, Chairman; W. H. Hems, Secretary-Treasurer; Bart Howard, John Campbell and Richard McDonald, Board of Managers—was handled by Allan Burnard, Chairman of the sponsoring Winnipeg Chapter.

Among those present to wish the 35 members of Golden West good luck were: H. P. Baker, Mayor of Regina; Hon. R. Brown, Minister in Charge of Saskatchewan Power Corp.; H. I. Nicholl, Superintendent, City of Regina Light and Power Dept.; A. Pratt, Superintendent, City of Weyburn Light and Power Dept., and representatives of the Architectural Association, Professional Engineers and Optometrist Society of Saskatchewan.

(News continued on page 31A)



with *Kopp Engineered* Lighting Glassware

LENSES . . . COLOR FILTERS . . . COVER GLASSES

There's one important point of similarity in the various examples of lighting glassware seen here. Size, shape and glass composition are different in each case; but they are all engineered by Kopp technicians *to do a specific job.*

Some applications call for high strength and other physical characteristics, as well as light distribution and color transmission. In others, controlled light—whether concentrated, directed or diffused—may be as significant as dimensional stability, or heat-resistance. In fact, mechanical and transmission properties vary with each product, depending upon its end use.

Problem is—to engineer these items with the right combination of properties to meet individual application requirements. And Kopp engineers are specialists at doing just that. Write us, at Swissvale, Pennsylvania, about your needs. *Ask for bulletin 553-A on Kopp-Engineered Glass.*

Beneficial Properties

IMPACT RESISTANCE
BEAM CONTROL
HIGH TEMPERATURE CHARACTERISTICS
DIMENSIONAL STABILITY
ACCURATE COLOR VALUES
HIGH PHYSICAL STRENGTH
THERMAL-SHOCK RESISTANCE
CHEMICAL DURABILITY
ELECTRICAL ADVANTAGES

SPECIALISTS IN CUSTOM-BUILT LIGHTING GLASSWARE

Kopp Glass, INC.

KOPP GLASS

. . . and now the

BROADSTREETER

turns night into day . . . with real economy every mile of the way!

a new fluorescent luminaire by **METCO** *for*

STREETS · EXPRESSWAYS
PARKING AREAS
SERVICE STATIONS
SHOPPING CENTERS
INTERCHANGES
PLANT SECURITY LIGHTING

metco Lighting

NEMA

cwa-li

Write for BULLETIN B559 and photometric data today.

METALCRAFT PRODUCTS CO., INC.
6225 State Road, Philadelphia 35, Pa.

More lumens per watt with less glare. Designed for latest high wattage lamps. Types III and IV lighting distribution.

Good color rendition with low glare factor.

Fully weatherproofed, insect-proofed. All aluminum, heliarc seam welded. Diffuser hinges from either side.

Lower lamp and transformer replacement cost.

Cool operating, instant starting, instant re-starting.

Completely self-contained, delivered ready for mounting and wiring to circuit.

(*News continued from page 28A*)

Overseas Visitors Enjoy British IES Jubilee

For three days, June 11, 12 and 13, the Illuminating Engineering Society in London was host to some 75 delegates (enroute to Brussels) from 21 different countries. The occasion was part of the British Society's Golden Jubilee, celebrating the fiftieth anniversary of the IES in England. Their splendid program, which started each morning at the British Lighting Council in London, was under the direction of George F. Cole, IES Executive Secretary. Assisting him were a number of Society members acting as Stewards.

Bus tours took the group through such outstanding installations as Gatwich Airport, New Crawley Town, the General Electric Research Laboratories, the BBC TV Centre, Riverside Studios, Thorn House, the Houses of Parliament and an unforgettable boat tour of floodlighting of London as seen from the River Thames.

Social entertainment of the foreign guests was as delightful as the tours were interesting. Luncheon one day was at the centuries-old Burford Bridge Inn, at Dorking, with dinner at Gatwich Airport. There was also a luncheon the following day, at King's Head, Harrow, and a high tea served at the GE Research Laboratories.

A very rare privilege was arranged for the overseas guests of the British IES in the dinner which concluded their program. This was held in the dining hall of the House of Commons and sponsored by Mr. Royle, M.P. Mr. Royle himself conducted parties through both Houses, explaining the procedures and traditions of this mother of parliaments. He was introduced and thanked by H. G. Campbell, President-Elect of the British IES, in the absence of the current President, C. C. Smith.

All of the visitors, and certainly the 15 from the United States, greatly appreciated and vastly enjoyed the interesting inside view of British installations, and the warm hospitality of their English hosts.

$100,000 Consumer Contest To Be Sponsored by EEI

As part of its National Electric Living Program, the Edison Electric Institute is sponsoring, this fall, a $100,000 Consumer Contest. Grand prizes in the contest will be four "Light for Living Medallion Homes," based on winning designs in the recent EEI student-architects' contest.

This contest, designed to educate the consumer, begins with distribution, to contestants, of a booklet on good home lighting. The contestant is required to answer 20 true-false questions based on the text of the booklet and then write a 20-word statement on why he would like to live in a "Light for Living" home.

Announcement of the contest will be in a two-page spread in the September 14th issue of *Life* magazine, with full-page follow-up ads in the October 10th and November 7th issues of the *Saturday Evening Post* and the October 13th issue of *Look*. Entry blanks and booklets will be available at retail stores and fixture distributor showrooms.

The first model home, based on one of the winning student designs, is expected to be completed shortly and will be opened to the public in mid-September, coinciding with American Home Lighting Fixture Month, National Home Week, Parade of Homes and the launching of the contest in *Life*. Each of the homes to be awarded as prizes was designed to accommodate a family of four and to be built for under $20,000, exclusive of lot but including all electrical equipment and major appliances.

SCHEDULED EVENTS

August 24-26, 1959 — International Association of Electrical Inspectors (Northwestern Section), Seattle Hotel, Seattle, Wash.

August 31-September 2, 1959 — International Association of Electrical Inspectors (Southwestern Section), Flamingo Hotel, Santa Rosa, Calif.

September 7-11, 1959 — National Technical Conference of the Illuminating Engineering Society, Hotels Fairmount and Mark Hopkins, San Francisco, Calif.

September 10-11, 1959 — Society of Plastics Industry, French Lick Sheraton, French Lick, Ind.

September 14-16, 1959 — International Association of Electrical Inspectors (Eastern Section). (Location unknown.)

September 14-17, 1959 — Institute of Traffic Engineers (Annual Meeting), Commodore Hotel, New York, N. Y.

September 25-26, 1959 — International Association of Electrical Inspectors (Canadian Section), Montreal, Que.

September 30-October 2, 1959 — Canadian Electrical Manufacturers Association, Sheraton-Brock Hotel, Niagara Falls, Ont.

October 5-7, 1959 — International Association of Electrical Inspectors (Western Section), Schroeder Hotel, Milwaukee, Wis.

October 5-10, 1959 — Society of Motion Picture and Television Engineers, Hotel Statler, New York, N. Y.

October 11-16, 1959 — American Institute of Electrical Engineers (Fall General Meeting), Chicago, Ill.

October 12-14, 1959 — International Association of Electrical Inspectors (Southern Section), Heidelberg Hotel, Jackson, Miss.

October 12-14, 1959 — National Electronics Conference, Inc., Hotel Sherman, Chicago, Ill.

October 12-16, 1959 — American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 13-15, 1959 — Electrical Progress Show, Convention Hall, Philadelphia, Pa.

October 15-17, 1959 — National Society of Professional Engineers (Fall Meeting), Olympic Hotel, Seattle, Wash.

October 19-20, 1959 — Annual Meeting of the United States National Committee (C.I.E.), Nittany Lion Inn, State College, Pa.

October 20-22, 1959 — Tenth National Conference on Standards, The Sheraton-Cadillac Hotel, Detroit, Mich.

November 2-5, 1959 — Eleventh Exposition of the Air-Conditioning and Refrigeration Industry, Convention Hall, Atlantic City, N. J.

November 9-12, 1959 — National Electric Contractors Association and Fifth National Electrical Exposition, Miami Beach, Fla.

November 9-13, 1959 — National Electrical Manufacturers Association, Traymore Hotel, Atlantic City, N. J.

November 29-December 4, 1959 — The American Society of Mechanical Engineers, Chalfonte-Haddon Hall, Atlantic City, N. J.

January 12-15, 1960—The Society of Plastics Engineers, Inc., 16th Annual Technical Conference, The Conrad Hilton Hotel, Chicago, Ill.

January 31-February 5, 1959—American Institute of Electrical Engineers, Winter General Meeting, New York, N. Y.

February 25-26, 1959 — Annual National Wiring Sales Conference, Warwick Hotel, Philadelphia, Pa.

ABOUT PEOPLE

Following a recent meeting of the Board of Directors of Appleton Electric Co., Chicago, President **Arthur I. Appleton** announced the following executive appointments: **F. W. Wehrheim,** vice-president directing the executive level planning for the company; **E. V. Aldridge,** vice-president—sales; **S. Peter Lambros,** vice-president—administration and planning, a new position; **Phillips M. Darby,** general sales manager; **John P. Dwyer,** sales manager—Unilet Division; **Thomas A. Strock,** sales manager—Reelite Division.

Bruce A. Everly has been named marketing manager for the Lighting Division of Westinghouse Electric Corp., with

(*Continued on page 32A*)

(Continued from page 31A)

headquarters at the Division's main manufacturing plant in Cleveland, Ohio. Mr. Everly, former sales manager of inside apparatus and supplies for Westinghouse Electric Supply Co., succeeds **A. W. Larson** in the marketing post. Mr. Larson has been appointed sales manager of the Bryant Electric Co., Bridgeport, Conn., a Westinghouse subsidiary.

The American Society of Heating, Refrigerating and Air Conditioning Engineers has announced the appointment of **Robert C. Cross** as Executive Secretary. Mr. Cross, who had been Executive Secretary of the ASRE prior to the merger of that group with the ASHAE, succeeds **Aubry V. Hutchinson.** Mr. Hutchinson has been designated Executive Secretary Emeritus and will continue to serve the Society in an advisory capacity.

Columbia Electric Co., Inc., Dallas, Texas, a subsidiary of Columbia Electric & Manufacturing Co., Spokane, Wash., has named **E. Jerry Whitlow** as general sales manager. Mr. Whitlow was formerly a vice-president with McClure Electrical Co.

John C. Virden Co., Cleveland, Ohio, has announced the addition of two sales representatives to their force. **Ray E. Wendling,** Phoenix, will handle the Virden products in Arizona, and **Marion L. Dick,** Milwaukee, will service the state of Wisconsin. In another announcement, the appointment of **William H. Rorabaugh** as general manager of Lighting Dynamics, Virden subsidiary in Dallas, Texas, was made known. Mr. Rorabaugh was formerly assistant general manager and lighting manager of the Electrical Distributing Division, Noland Co.

Robert H. Shaffer has been named vice-president in charge of manufacturing for Curtis-AllBrite Lighting, Inc., with offices at the company's headquarters plant in South San Francisco, Calif. Mr. Shaffer formerly served as works manager of the firm's AllBrite Division.

General Electric Lamp Metals and Components Department, Cleveland, Ohio, has announced the promotion of **Adam MacKenzie** to marketing manager of the Department. Mr. MacKenzie, who has been with G-E for 35 years, most recently served as manager of the Cleveland Welds Plant of the Department. He succeeds J. W. Forbes.

Union Metal Mfg. Co., Canton, Ohio., has announced the appointment of **Calvin Friar** as assistant district manager in the Northern California-Northern Nevada District. Mr. Friar will work with **Charles Strom,** district manager, from the District headquarters in San Francisco.

Allyn W. Falls, management consultant, is now associated with Ebasco Services, Inc., in the San Francisco offices of the management consulting, engineering and construction firm. Mr. Falls most recently served as assistant to the president of D. Cisneros and Co., a Venezuelan firm, representing General Dynamics Corp.

Marshall N. Waterman, commercial engineering manager of Westinghouse Lamp Division, Bloomfield, N. J., and former IES President, represented the American lamp industry at the lamp group meetings of the International Electro-Technical Commission in Madrid, Spain. During the July meetings of the IEC, representatives from all over the world discussed standardization of the electrical and mechanical characteristics of equipment, as another step toward the achievement of their ultimate goal—the complete interchangeability of light sources manufactured anywhere in the world.

Pyle-National Co., Chicago, Ill., has named **Curtis H. Stout, Inc.,** as representatives in the south-central area. The

(Continued on page 34A)

Important News Release!

From: National Technical Conference Committee
Contact: John Walsh
Release: IMMEDIATE

Deep sea fishing party, western-style chuck wagon dinner, banquet, swimming and golf at the Orinda Country Club—these are only some of the "extras" being planned for IES'ers who attend the National Technical Conference in San Francisco, September 7-11.

The technical program, with nine top-level sessions scheduled, features papers on—for example—new uses of electroluminescence, uses of computers for fixture design, comfort evaluation of roadway lighting and many more. There are 39 papers in all, covering important developments in illumination during the past year.

Special technical highlights are reports on two IERI projects, "Studies of Reflected Glare in Sample Office Areas" and "Determination of Light Levels for Roadway Visual Tasks" by Dr. H. Richard Blackwell and B. S. Pritchard and an invited paper on "Lighting of Streets and Public Buildings in France" by L. Gaymard, Chief Street Lighting Engineer, Electricité de France.

The ladies committee has planned exciting things too. For wives who attend the Conference, there will be (in addition to the regular social program) a sightseeing boatride on San Francisco Bay, a tour of the Napa Valley wine country (with samples) and a fashion show in San Francisco's famous Chinatown.

If you haven't signed up yet—better hurry. Advance registrations are being recorded at IES Headquarters by John Michel, Membership Secretary, or you can register when you get there. The Fairmont and Mark Hopkins Hotels are Conference headquarters.

So, "Keep your date at the Golden Gate," IES National Technical Conference, September 7-11, 1959.

Address Changes should be reported to IES Headquarters by the first of any month, to insure the uninterrupted mailing of IE and other Society communications.

after-glow

NEW, PROJECTED LETTER

FLUORESCENT EXIT UNITS by PERFECLITE

SURFACE TYPE UNIT

Check These Superior Features:

Phosphorescent Lucite panel gives ½ hour after-glow should the circuit become dead. 6" projected letters. Available in models for all surface type as well as recessed installations. Mounted from top, back, side or from a pendant. Surface models are also available for either single or double face use. Pivot hinged, die formed 20 ga. steel frames for easy servicing. Surface type boxes are made of 18 ga. press drawn steel, ½" KO's top and side. Recessed boxes are of 20 ga. press drawn steel, six ½" KO's.

Lucite faces available in 4 color combinations — with or without arrows. Completely wired for two T-5 6-watt lamps. 118-V. AC ballasts. Also available for use in 277-V. systems.

You reduce installation costs, make every building safer when you select Perfeclite unbreakable projected letter fluorescent exit signs. For further information, mail the attached coupon today!

PERFECLITE PRODUCTS — THE MARK OF LIGHTING SERVICE

Units are Underwriters' Laboratories, Inc., approved, and comply with National Electrical Code.

THE PERFECLITE COMPANY

1457 EAST 40th STREET • CLEVELAND 3, OHIO

Please send me the Perfeclite Data Folder EX-58 C.

NAME _____

ADDRESS _____

CITY _____ STATE _____

(*Continued from page 32A*)

Stout company has offices in Jackson, Miss.; Little Rock, Ark.; Memphis, Tenn.; and New Orleans and Shreveport, La. Also announced by Pyle-National was the transfer of **D. W. Jackson** from New Orleans to Houston, where he will serve as a sales representative.

Earl Steinke has joined the engineering staff of Lighting Products, Inc., Highland Park, Ill., as a design engineer. Prior to this appointment, Mr. Steinke was associated with Luminous Ceilings, Inc., Chicago, Ill.

John R. Hayes and **Paul H. Noe**, Hayes and Noe, Atlanta, Ga., were recently named as sales representatives for Sola Electric Co. Hayes and Noe will handle the Sola lighting transformer line in Georgia, Tennessee, Alabama, North Carolina, South Carolina and western Florida.

Moe Light Division, Thomas Industries, Inc., has announced the appointment of **R. L. Patrick** as district sales representative in Montana, northern Idaho and eastern Washington.

George R. Butler is on leave of absence from the Rochester Gas and Electric Co., to serve as manager of the Certified Lighting Bureau in Rochester, N. Y.

MODERATOR Gilbert Trosper (right) fires a replica of an early San Francisco street light, official symbol of the Lamplighters, Golden Gate Section Street Lighting Committee, to open the first of a series of street lighting meetings sponsored by the committee in four western cities. The panel of experts, l. to r., R. M. Harris, Joslyn Pacific Co.; E. B. Karns, Westinghouse; A. D. Harrington, General Electric and W. B. Blackford, Line Materials Industries, keynoted meetings in San Francisco, Los Angeles, Seattle and Salt Lake City.

BOOKS AND PAMPHLETS

1958 Book of ASTM Standards, American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Price for complete ten-part set, $116. Prices for individual sections given below.

Part 1. Ferrous Metals Specifications (Except Test Methods), 1620 pages, 291 standards, $12.

Part 2. Non-Ferrous Metals Specifications (Except Test Methods), Electronic Materials, 1380 pages, 251 standards, $10.

Part 3. Metals Test Methods (Except Chemical Analysis), 992 pages, 121 standards, $10.

Part 4. Cement, Concrete, Mortars, Road Materials, Waterproofing, Soils, 1456 pages, 338 standards, $12.

Part 5. Masonry Products, Ceramics, Thermal Insulation, Sandwich and Building Constructions, Acoustical Materials, Fire Tests, 1142 pages, 210 standards, $12.

Part 6. Wood, Paper, Adhesives, Shipping Containers, Cellulose, Leather, 1040 pages, 219 standards, $10.

Part 7. Petroleum Products, Lubricants, Tank Measurements, Engine Tests, 1516 pages, 260 standards, $12.

Part 8. Paint, Naval Stores, Aromatic Hydrocarbons, Coal, Coke, Gaseous Fuels, Engine Antifreezes, 1632 pages, 353 standards, $12.

Part 9. Plastics, Electrical Insulation, Rubber, Carbon Black, 2056 pages, 380 standards, $14.

Part 10. Textiles, Soap, Water, Atmospheric Analysis, Wax Polishes, 1524 pages, 280 standards, $12.

American Standard Method for Determining **Special Purpose Photographic Exposure Indexes** for Short and Long Exposure Times, PH 2.14-1958, available from American Standards Association, 155 East 44th St., New York 17, N. Y., 80 cents.

A method for measuring and specifying film speeds at exposure times longer than 1/20 second and shorter than 1/80 second is contained in this Standard. A more accurate daylight index for sensisivity of photographic materials can be obtained for longer or shorter exposure times by applying "reciprocity factors," determined by this Standard, to the Speed as determined by American Standard PH2.5-1954.

Proceedings of the American Society for Testing Materials, Vol. 58, 1958, published by ASTM, 1916 Race St., Philadelphia, Pa. 1430 pp., $12.00.

This record of the Society's technical accomplishments during the year includes 51 technical papers and discussions on a wide variety of subjetes, 74 technical committee reports, a summary of the proceedings of the ASTM 61st Annual Meeting and the annual report of the Board of Directors on administrative and financial matters of the Society. In addition, it lists all symposia and other special sessions published separately as Special Technical Publications and all papers which were published in the *ASTM Bulletin*. A subject and author index is also included.

Inter-reflections and Flux Distributions in Lighted Interiors, by J. A. Lynes, Illuminating Engineering Society (London), 32 Victoria Street, London, SW1. 12 pages, paper bound, 5/6d.

The first of a new series of publications by the British Society, IES Monograph No. 1 describes a method for calculating the distribution of light due to multiple reflections inside a room.

This monograph service has been inaugurated to publish original and fundamental work on lighting for which no suitable channel of publication had previously existed. Frequency of publication will depend upon availability of suitable material. It is assumed that there will be not more than two or three each year.

Book covers for school books, available from Better Light Better Sight Bureau, 750 Third Ave., New York 17, N. Y.,

(*Continued on page 37A*)

Distinctive Lighting at Modest Cost . . . for Interiors of All Types

SABRE* by miller

General Office Area

Legal Conference Room

Dental Office

Furniture Store

Restaurant-Luncheonette

Rarely do you find a fluorescent lighting fixture that is *truly* distinctive. Occasionally, some measure of distinction is reached through appearance, lighting performance, or decorative effect produced. SABRE by Miller, however, achieves *true distinction* through a unique blend of *all* these virtues. And, it's available at modest cost.

SABRE is rapidly becoming one of the most wanted fluorescent fixtures in America. Pictured are just a few typical interiors where it is already doing a superlative lighting job. SABRE fits interiors of all types — large or small, new or old.

Styling with trim, crisp lines produces a sweeping effect and enhances decor . . . efficiency of 74½% means fewer fixtures needed per footcandle to make today's high lighting levels possible . . . one-piece, wrap-around refractor of prismatic, crystal clear plastic provides sparkle, with comfortable viewing from all angles.

For a lighted demonstration, contact your Miller representative. And, for full catalog information on this unique fixture write Dept. 8959.

THE miller COMPANY • MERIDEN • CONN.

LIGHTING BY miller SINCE 1844

*Reg. Trade Mark

with

APPLETON Industrial Lighting

...you can see the difference!

Higher Production • Fewer Rejects • Improved Employee Relations • Extended Safety Records

"INTENSO"

alzak* aluminum floodlights

FOR STORAGE YARDS, ATHLETIC FIELDS, and other large areas

The Intenso Alzak* Aluminum floodlight provides high-intensity, trouble-free illumination year-round. Each light complete with 4-ft. cord. Available in 18″ and 20″ etched or polished reflectors, 20° to 90° beam spread. For 750-1000 or 1500 Watt PS-52 lamps and 400 Watt Mercury Vapor lamps.

Split Second Rear Relamping

No tools needed . . . No nuts or bolts! Rear lid with lamp opens wide for quick, easy access.

Rifle Like Aiming

After servicing, just flip lid down and clamp! Due to impregnated asbestos gasket seal, unit is now weatherproof. Exclusive louver ventilation eliminates condensation. Aim by looking through peepsight, then lock in position . . . horizontal and vertical locking degree calibrations in each unit.

* A proprietary term of Aluminum Company of America

"EFU"

explosion-proof fluorescent fixtures

FOR HAZARDOUS LOCATIONS IN GRAIN MILLS, REFINERIES, CHEMICAL PLANTS, COLOR PRINTING PLANTS, PHARMACEUTICAL CONCERNS, ETC.

2, 3, and 4-lamp fixtures . . . Straight or angle mounting

Choice of "Pre-Heat," "Slimline," or "Rapid Start" ballasts. Designed for use with 40-Watt, 48″, T-12, and 85, 90, or 100-Watt, 60″, T-17 fluorescent lamps. End housings are cast aluminum with line connections made to a terminal block in the junction chamber.

Relamp from either end of the fixture . . . long lamp life, long ballast life without starters . . . quiet, flickerless operation . . . APPLETON factory seal eliminates external seals normally required within 18″ of arcing devices . . . These are quality features which give APPLETON "EFU" Explosion-proof fixtures their continually growing acceptance in all types of hazardous industrial applications.

The correct light for every industrial application—including hazardous locations—backed by the technical excellence and experience of APPLETON'S vast production facilities assures you of lighting products designed to meet your needs. Write for complete information today . . . APPLETON—Standard for Better Lighting.

FLOODLIGHTS • REFLECTORS • DIFFUSERS • GROUP LIGHTS • HIGH MOUNTING FIXTURES
STAKLIGHTS • WALK LIGHTS • YARD LIGHTS • SERVICE STATION LIGHTS

Also Manufacturers Of:

Sold Through Franchised Distributors Only

APPLETON ELECTRIC COMPANY • 1712 Wellington Avenue • Chicago 13, Illinois

(Continued from page 34A)

have been designed to be suitable for local distribution by electric utilities. The new covers carry the same copy theme as the 1958 version, but have new art-work and a new finish. Prices are on a sliding scale based on quantity.

Howard Jasnau

NEW MEMBERS

At the meeting of the IES Council Executive Committee on July 23, 1959, the following were elected to membership. Names marked * are transfers from Associate Member Grade. Names marked ** are transfers from Student Member Grade.

ALABAMA SECTION

Associate Members:

Ashbee, J. C., 20 S. Conception, Box 1211, Mobile, Ala.
Bryars, H. R., Economy Electric Construction Co., Mobile, Ala.
Cain, E. M., Jules L. Brana Co., Inc., Mobile, Ala.
Funderburk, Therlo, Palmer & Baker Engineers, Inc., Mobile, Ala.
Gurley, James, Jr., 1575 E. Octavia Drive, Mobile, Ala.
Henderson, C. S., Noland Co., Inc., Montgomery, Ala.
Ledbetter, M. P., Turner Supply Co., Mobile, Ala.
Mathews, L. O., Jr., Mathews Electrical Service, Mobile, Ala.
McKinney, E. B., Gregory-Salisbury Inc., Mobile, Ala.
Moss, A. J., General Electric Supply Co., Mobile, Ala.
Wilson, J. H., Jr., Coastal Electric Co., Mobile, Ala.

Student Member:

Andrews, E. L., University of Alabama, Mobile, Ala.

BLUENOSE CHAPTER

Associate Member:

Sadofsky, Ralph, Union Electric Supply Co., Ltd., Halifax, N. S.

BUCKEYE CHAPTER

Member:

*Corn, H. S., Columbus & Southern Ohio Electric Co., Columbus, Ohio.

Associate Members:

Bead'e, H. E., North American Aviation, Inc., Columbus, Ohio.
Beck, A. C., General Electric Co., Columbus, Ohio.
Frick, R. L., General Electric Supply Co., Columbus, Ohio.
Grey, L. P., Litecraft Mfg. Corp., Columbus, Ohio.
Kaufher, Martin, Electric Motor & Control Corp., Columbus, Ohio.
Leahy, M. J., M. J. Leahy Co., Columbus, Ohio.
Lubin, Sam, Elgee Electric Co., Columbus, Ohio.
McIntire, B. S., General Electric Co., Columbus, Ohio.
Mast, L. R., H. A. Williams & Associates, Columbus, Ohio.
Monks, W. E., Sims, Cornelius & Schooley, Columbus, Ohio.
Murnane, T. A., General Electric Supply Co., Columbus, Ohio.
Risler, H. E., Westinghouse Electric Supply Co., Columbus, Ohio.
Schumm, H. C., Gould H. Ayres & Assoc., Columbus, Ohio.
Smith, G. T., McCleery Carpenter Electric Co., Columbus, Ohio.
Springer, D. C., 1527 Waltham Road, Columbus, Ohio.

CENTRAL ILLINOIS CHAPTER

Associate Member:

Wineke, J. W., Associate of George P. Wearda, Architect, Pekin, Ill.

CENTRAL KANSAS CHAPTER

Associate Members:

Englebright, Dorothy S., Architectural Lighting, Inc., Wichita, Kans.
Green, J. D., The Southwestern Electrical Co., Wichita, Kans.

CENTRAL OKLAHOMA CHAPTER

Associate Members:

Harris, William, Oklahoma Electrical Supply Co., Oklahoma City, Okla.
Jones, C. W. Jr., Oklahoma Electrical Supply Co., Oklahoma City, Okla.

CHICAGO SECTION

Associate Members:

Butler, C. M., Jefferson Electric Co., Bellwood, Ill.
Davies, R. B., Advance Transformer Co., Chicago, Ill.
Hanan, J. P., Coyne Electrical School, Chicago, Ill.

Student Member:

Hotvedt, Robert, University of Illinois, Urbana, Ill.

CLEVELAND SECTION

Associate Members:

Bentz, C. H., General Electric Co., Cleveland, Ohio.
Jennings, K. C., The Union Metal Mfg. Co., Canton, Ohio.

COASTAL EMPIRE CHAPTER

Associate Members:

Cain, B. C., Cain Electrical Contractors, Savannah, Ga.
Jarrell, E. F., Baker & Jarrell Electric Supply, Inc., Savannah, Ga.

EDMONTON CHAPTER

Associate Member:

Louden, A. H. R., A. H. R. Louden Agency, Edmonton, Alta.

FOREIGN NON-SECTION

Associate Members:

Fouts, L. R., Luxor Lighting Products Inc., Honolulu, Hawaii.
Maxia, Alfonso, via Andrea Verga 3, Milano, Italy.

GEORGIA SECTION

Members:

*Brun, John, Westinghouse Electric Corp., Atlanta, Ga.
Hitz, T. R., Jr., Bush-May & Associates, Atlanta, Ga.
Riker, E. L., Newcomb & Boyd, Consulting Engineers, Atlanta, Ga.

Associate Members:

Hines, D. L., Walter H. West & Associates, Atlanta, Ga.
Long, C. D., Bush-May & Associates, Atlanta, Ga.
Peele, Q. J. Jr., Duggan Optical Co., Atlanta, Ga.
Trobaugh, J. L., Georgia Power Co., Atlanta, Ga.

GOLDEN GATE SECTION

Associate Members:

Govan, W. S., Prescolite Mfg. Co., Berkeley, Calif.

(Continued on page 42A)

THE FIRST UNIVERSAL T-RAIL SUSPENSION SYSTEM...

COLUMBIA'S T-1000

No holes to match up in this system!
No holes to drill in this system!
All of the parts are automatic and adjustable. They can be readjusted or moved at any time without injuring the parts or requiring replacements. The complete simplicity of T-1000 makes for rapid installation... only a screwdriver and pliers are needed. T-1000 adapts readily to most diffusers you may desire although we think the ½" x ½" x ½" KOLDBOND* LOUVER, as illustrated below, is a perfect companion for T-1000.

*Copyright

Send for catalogued details and specifications today.

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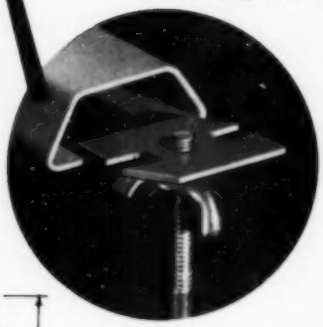
DEPT. I-8 • N. 2310 Fancher Way • SPOKANE 10, WASHINGTON
1315 EAST THIRD STREET • LOS ANGELES, CALIF.

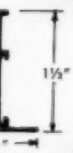
COLUMBIA ELECTRIC CO., INC.
7900 SOVEREIGN ROW • DALLAS 35, TEXAS

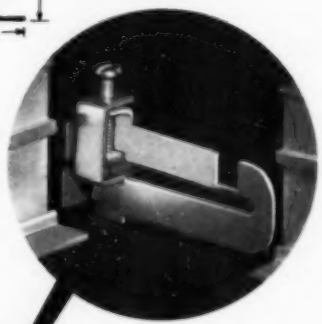
Member Eye Fidelity Lighting Group

Patents applied for

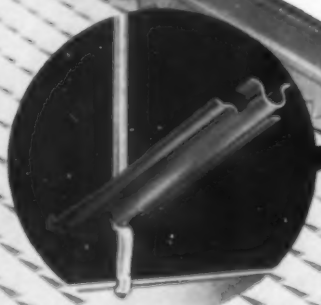


HANGER PLATE
T-RAIL CONNECTOR





Rail is extruded aluminum with alumilite finish



HANGER CLAMP

HOW CBM ASSURES YOU BETTER BALLAST VALUE

Heat measurement study under way at ETL for joint CBM-RLM-NEMA committee . . . aims to improve fixture and ballast heating conditions . . . assure better performance and service

This maze of wires above is needed to connect with thermocouples in fixtures, ballasts and other parts, so temperatures can be measured at different points. Screening shields break up drafts from air conditioning, help keep ambient constant.

NEW streamlined fluorescent fixtures, new high output lamps and space-saving mounting trends have often brought higher channel ambient temperatures . . . *and problems to user and installer!*

To deal with them, Certified Ballast Manufacturers led in setting up a joint technical committee with RLM and NEMA fixture makers. For this group, ETL is measuring temperature at 50 different points in representative fixtures, to try to pinpoint the part each of the lighted fixture components plays in the total temperature rise. Already progress has been made . . . and more is expected.

But this is just one contribution by CBM toward better ballast value. Behind it all is the CBM specification which assures quality performance, including:

Long lamp life • High power factor • Positive starting • Lasting service • Peak lighting performance

. . . with conformance to spec checked and certified by ETL. Naturally, CBM Ballasts are UL listed!

Get the full story on why it pays to specify fluorescent fixtures equipped with ballasts that are Certified CBM. Write for: "To Insure Your Lighting Investment", Certified Ballast Manufacturers, 2112 Keith Building, Cleveland 15, Ohio.

CBM CERTIFIED by ETL

CERTIFIED BALLAST MANUFACTURERS

2112 KEITH BUILDING
CLEVELAND 15, OHIO

Participation in CBM is open to any manufacturer who wishes to qualify

BETTER LIGHTING IS EASY

TO INSTALL AND MAINTAIN WITH JOB-DESIGNED FIXTURES BY

WHEELER • FULLERTON

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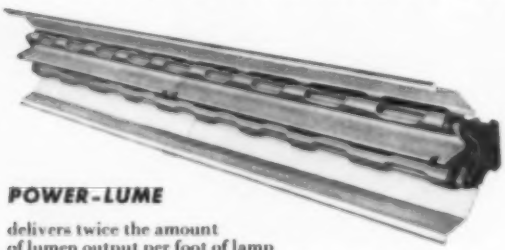

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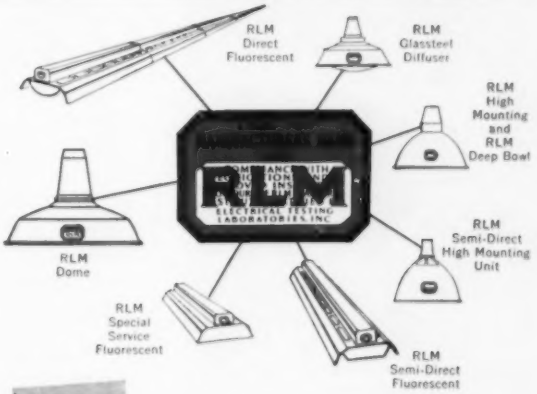

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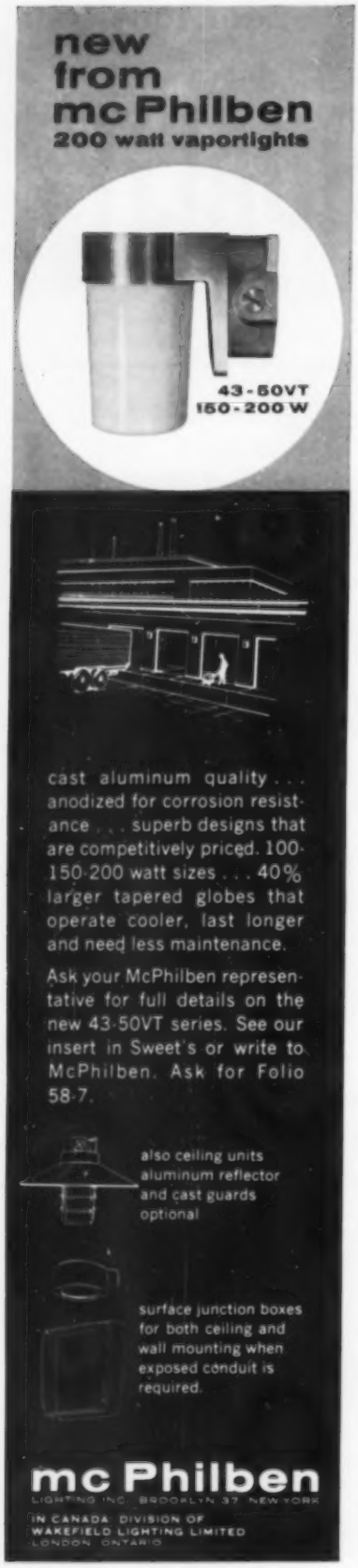
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(*Continued on page 44A*)

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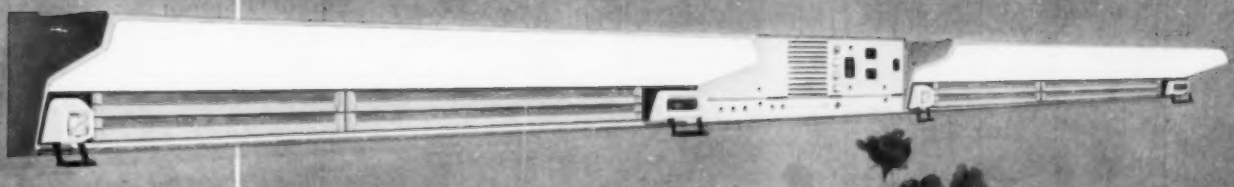

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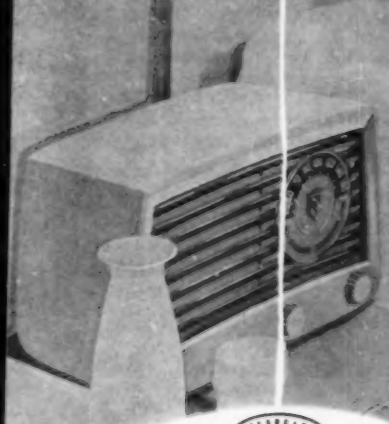

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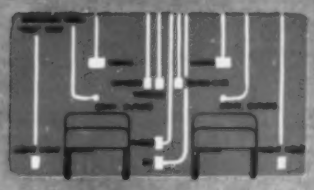

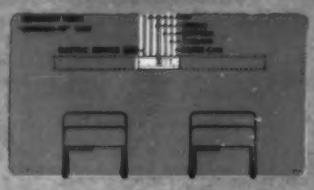

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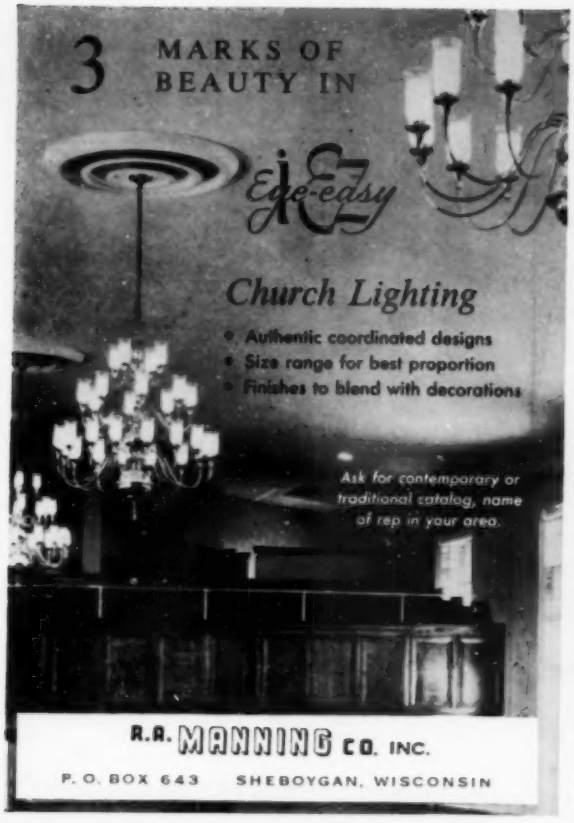
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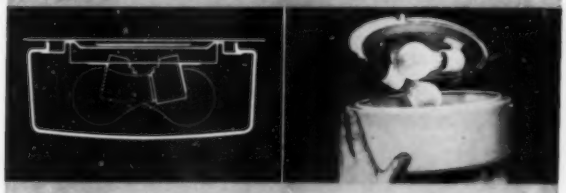

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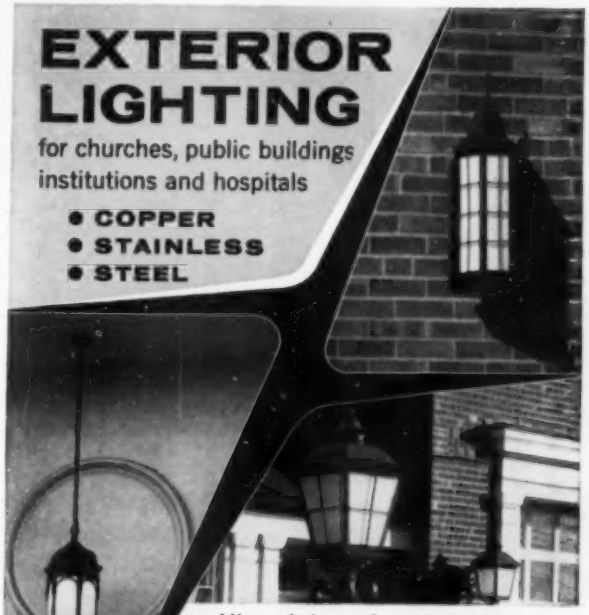

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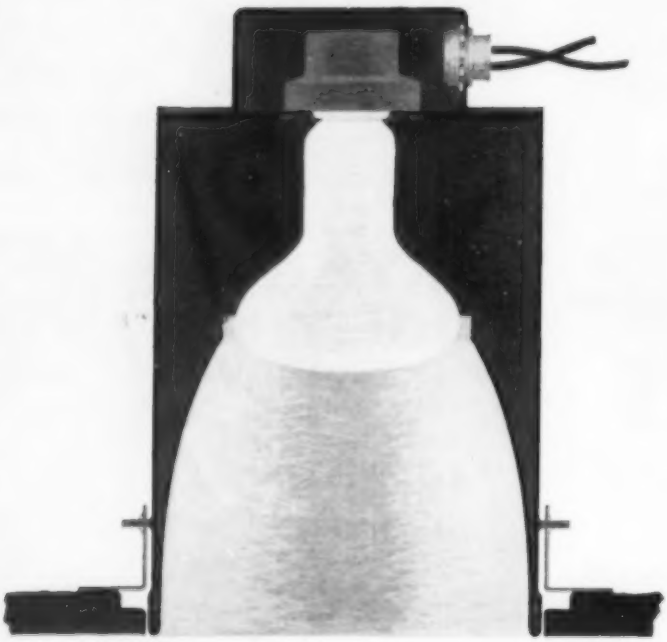

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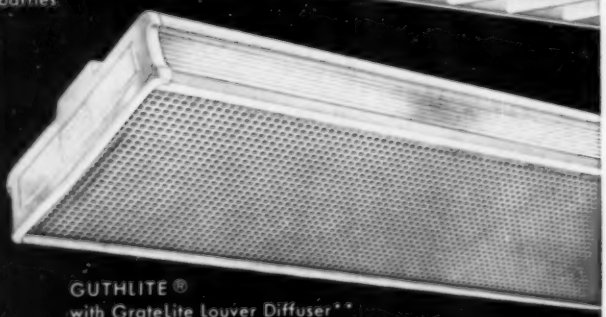
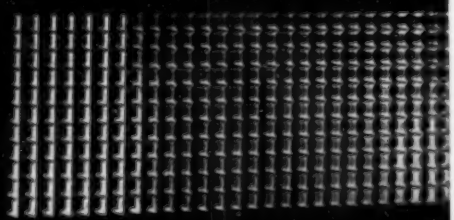


GUTHLITE®
with GrateLite Louver Diffuser**



PRISMOID GRATELITE†

Guth LIGHTING

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**®U. S. Pat. No. 2,745,001
Can. Pat. 1957, No. 538,245